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BULLETIN No. 9.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF FORESTRY.

REPORT

ON THE

USE OF METAL RAILROAD TIES

AND ON

PRESERVATIVE PROCESSES AND METAL TIE-PLATES FOR WOODEN TIES.

BY

E. E. RUSSELL TRATMAN, A. M. AM. SOC. C. E.

[SUPPLEMENTARY TO REPORT ON THE SUBSTITUTION OF METAL FOR WOOD IN RAILROAD TIES, 1890.]

PREPARED UNDER THE DIRECTION OF

B. E. FERNOW,
Chief of Division of Forestry.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF FORESTRY,
Washington, D. C., October 15, 1894.

SIR: I have the honor to submit herewith for publication a report on the use of metal railroad ties, by Mr. E. E. Russell Tratman, as a supplement to Bulletin No. 4 of this Division [illegible]

LIST OF ILLUSTRATIONS.

Plate 1. Steel Tie of the New York Central Railroad.
Plate 2. Various types of Ties and Tie-plates.
Plate 3. Various types of Tie-plates.
Plates 4 and 5. Historical development of Ties and Tie-plates.

Reference to plates 31 to 35 are meant for plates 1 to 5 of this report. References to plates 1 to 30 are meant for plates in the original report, Bulletin 4. Occasionally, however, references to plates 1 to 5 are also meant for plates of the present report and should be so corrected.

[illegible] preservative processes and metal tie-plates may be applied to wooden ties with advantage, and thereby no doubt the time will be postponed when the better but more expensive metal tie shall be adopted.

Respectfully,

B. E. FERNOW,
Chief of Division.

Hon. J. STERLING MORTON,
Secretary.

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SUP

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF FORESTRY,
Washington, D. C., October 15, 1894.

SIR: I have the honor to submit herewith for publication a report on the use of metal railroad ties, by Mr. E. E. Russell Tratman, as a supplement to Bulletin No. 4 of this Division, on the same subject. The subject of wood preservation and other economies in the use of wood in railroad construction, which were treated in Bulletin No. 4, also find additions in this report, together with a republication of parts of Bulletin No. 1, the issue of which is exhausted.

The question of the substitution of metal for wood in railroad ties has progressed steadily since the first report published in 1890, until now more than 35,000 miles, or, allowing for omissions in the report, about 20 per cent of the railroad mileage of the world outside the United States and Canada is laid on metal. Although progress in this direction in our country has been slow, yet it can be a question of only a short time when this saving of forest supplies, which will at the same time insure greater efficiency, safety, and final economy, will be forced upon them by the waning of forest supplies, and as the railroad companies begin more and more to assume a permanent and less speculative character.

Meanwhile, as shown in the report, preservative processes and metal tie-plates may be applied to wooden ties with advantage, and thereby no doubt the time will be postponed when the better but more expensive metal tie shall be adopted.

Respectfully,

B. E. FERNOW,
Chief of Division.

Hon. J. STERLING MORTON,
Secretary.

LETTER OF SUBMITTAL.

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127 EAST TWENTY-THIRD STREET,
New York City, October 1, 1894.

SIR: Herewith I submit my second report upon the use of metal railway ties as a substitute for wooden ties, and upon the methods adopted for the preservation and protection of wooden ties.

Parts I and II, relating to metal track, are mainly supplementary to my former report on this subject (published as Bulletin No. 4 of the Forestry Division, in 1890), and should be studied and considered in connection with that report, for which purpose the original arrangement and classification have been followed so far as possible. This supplementary report practically covers a period of nearly five years, but it has not been attempted to procure returns from each railway mentioned in the report of 1890, so that the summarized statistics of mileage in all probability err considerably on the side of omission. Its purpose has rather been to record particulars of the experience and development during this period, but the aggregates of the mileage statistics show an increase in the proportion of track laid with metal ties to the total length of railways of the world (exclusive of the United States and Canada, which have a great railway mileage with an infinitesimally small percentage of metal track) from 13.2 per cent in 1890 to 17.2 per cent in 1894. Allowing for the incompleteness of the returns, as noted above, this means probably 20 per cent in 1894 as compared with 15 per cent in 1890. In general it is shown that metal ties have been successfully applied and are in successful use under all conditions of climate, traffic, and track, and in many cases under conditions approximating to these which obtain on railways in the United States.

In view of the possibilities of steel-tie manufacture as a new and important industry in this country, I have, in Part II, entered somewhat fully into particulars of manufacture, so that the report will be of interest and value to steel makers and workers as well as to engineers and railway men. It is of special importance to note that one American manufacturer estimates that 100-pound ties for main tracks can be made in quantities for less than $2 each, at present prices of steel; and that the price of metal is getting so low that there may be a future for this branch of manufacture on the score of low first cost alone. The report includes a large number of special and official returns from all parts of the world, and in this, as in the former report, I have given the main parts of these returns nearly in full, as well as a digest and review of the mass of information contained in the descriptive part of the report. The reason for this is that neither particularized nor generalized information is sufficient in itself for the purposes for which this report is intended. Had the returns and general information been given, without any review or comparison of their subject-matter, it would leave each reader to study out for himself the conclusions to be drawn; while, had the detailed information been merely summarized and digested, the reader would naturally be in doubt as to the amount and character of the information and the strength of the grounds upon which the conclusions presented were based. I have therefore given the important statements from individual returns, and have also presented a review of the whole matter, with the conclusions to be drawn therefrom. It may be permissible to note here that the original report has received considerable favorable commendation on the part of railway engineers and officers and the technical press. Only one adverse criticism has been received, and that claimed that injustice had been done by certain statements which were inaccurate, but on inquiry the original statements were officially indorsed as accurate. The present report is of even greater practical importance than the former one, which necessarily took up the matter historically in order to show the development of the metal-tie question, and thus a considerable portion was more matter of record than of experience. The report would not, however, have been complete if this matter had been omitted or neglected. In fact, one of the foreign engineering papers, in reviewing that report, stated that "It is now possible to form an accurate idea of what has been done and of what is being done in various countries, and with what degree of success."

Part III of this report, dealing with the economies which may be practiced in the use of wooden ties, has been added for the reason that while the more general use of metal ties may be looked forward to in the future, yet at the present time a matter of more immediate interest is the economical use of the present type of track, for the financial and physical benefit of the railways and for the preservation of the valuable timber resources of the country, which have been, and are being, dissipated and destroyed at an alarmingly rapid rate. The application of preservative processes not only effects economy by increasing the life of the tie and reducing the renewals and maintenance work (thus insuring a better and more permanent track), but in many cases it enables cheaper woods, not suitable for railway ties in their natural state, to be made use of, so that treated ties of this kind may be actually cheaper and have a longer life than untreated ties of originally better quality. As the life of ties in this country, however, is limited more frequently by the destructive effects of wear and consequent local rot at the rail seat than by the natural decay of the ties, the full benefit of the treated ties can not be made available unless means are taken to prevent such wear. For this purpose metal tie plates have been introduced, and their use has spread to an enormous extent during the past few years, owing to the great improvement which they effect in economy and efficiency of track for a very low first cost. These plates are used generally on untreated ties, as the adoption of preservative processes has been far less rapid than that of tie plates. It is safe to say that the use of such plates is one of the most important of modern steps in railway economy, but, as already noted, the full benefit of the expense involved in the treated ties and the metal tie plates can only be assured when both are used together.

While a very great reduction in the consumption of wooden ties may be effected by these means, I can not pass by this opportunity to refer to the extreme desirability of the adoption of a conservative forestry policy by the Government without delay, so as to preserve the remaining timber resources (the reckless, wanton, and often illegal destruction of which is matter of past and present history), not only for their natural benefits to the country as standing timber, but also for their value as a constant and recurring source of timber supply for commercial purposes, the source being in constant course of renewal under reforestation methods and practical forest management. The details of such work, and the satisfactory experience with Government management of forests in Europe, India, etc., have been published in other bulletins of the Forestry Division of the U. S. Department of Agriculture, and need only be referred to here.

In conclusion, while regretting that no greater progress can be reported in the use of metal ties in this country, I can not but feel that this limited progress is due to some extent to the more immediate and direct economies now being commendably effected by the other means above noted; nevertheless, judging from the progress and continued favorable experience in other countries, I still believe that the more extensive use of metal ties in this country has merely been postponed temporarily, and is still a very live issue for consideration.

I am, sir, respectfully yours,

E. E. RUSSELL TRATMAN,
Assoc. Mem. Am. Soc. C. E., M. Am. Inst. M. E.

B. E. FERNOW,
Chief of Forestry Division,
Department of Agriculture, Washington, D. C.

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CIRCULAR.

In order to perfect and complete the information gathered in these reports, readers are requested to note any omissions, corrections, etc., and transmit such, together with drawings, statistics, reports, etc., and other additional information relating in any way to the subjects treated and outlined in the schedule given below to the writer of this report, Mr. E. E. Russell Tratman, C. E., care of American Society of Civil Engineers, 127 East Twenty-third street, New York City, U. S. A.

OUTLINE OF INFORMATION IN RELATION TO RAILWAY TRACK AND TIES.

RAILWAY.

1. Name of railway.
2. Route.
3. Character (grades, curves, nature of country and soil, etc.).
4. Name of chief engineer or engineer of permanent way.
5. Climate, and effect on metal and wooden ties.
6. Character of traffic.
7. Number, weight, and speed of trains.
8. Weight of engines, weight on driving wheels, and length of wheelbase.
9. Construction of roadbed (drawing).
10. Material of ballast.
11. Behavior of same under ties.
12. Rail: weight, section, and length.
13. Rail fastenings: spikes, bolts, clamps, etc., (with drawings).
14. Rail joints: broken or even, suspended or supported.
15. Rail joints; arrangement of splice bars and bolts.

METAL TRACK.

1. Length of line laid.
2. Where laid.
3. Dates when laid.
4. Cross-ties, longitudinals or separate bearings (bowls, etc.).
5. General form (detail drawings).
6. Dimensions, including thickness.
7. Weight.
8. Material, and quality of same (send specifications).
9. Spacing, center to center.
10. Protective treatment (painting, tarring, anti-rust process, etc.).
11. Manufacturer.
12. First cost, at factory or delivered.
13. Attachments of rails (drawings).
14. Arrangements for curves.
15. Tie rods; if used; how attached and how adjusted for gauge.
16. Durability.
17. Number of renewals.
18. Expense of maintenance (statistics).
19. Reasons for using metal track.
20. Results, satisfactory or otherwise.
21. Is there trouble with—
    - (*a*) Rail attachments.
    - (*b*) Maintenance of track.
    - (*c*) Noise under train.
    - (*d*) Rust, corrosion, wear, cracks, or breakage.
22. Efficiency and economy as compared with wooden ties.
23. General remarks.
24. Opinions, or summary of experience.

WOODEN TIES OR SLEEPERS.

1. Material (send specifications.)
2. Where obtained.
3. Size of tie.
4. Cost of tie.
5. Number and cost of renewals.
6. Length of life of tie; how does it fail.
7. Statistics of consumption and renewals.
8. What extra fastenings are used on curves.
9. Spacing of ties, center to center.
10. What preservative process used; describe, with results.
11. Work done by railway or contractor.
12. Number of ties treated.
13. Length of life of treated ties.
14. Does treatment soften or harden the wood.
15. Wood used.
16. Cost of new tie and cost of treatment.
17. Are ties seasoned before use or before treatment.

TIE-PLATES.

1. Type of plate, with drawing.
2. Maker.
3. Material.
4. Dimensions, thickness, and weight.
5. How long used.
6. Placed on how many ties.
7. What wood are the ties.
8. Cost of plate.
9. How is plate fastened to the tie.
10. How is rail fastened to plate and tie.
11. Efficiency in making good track and reducing renewals of ties.
12. Is there trouble in keeping the plates tight on the ties (to prevent slapping or chattering).
13. Are they used on curves and at switches.

PART I.

USE OF METAL TIES ON RAILWAYS IN FOREIGN COUNTRIES AND IN THE UNITED STATES.

NOTE.—An asterisk (*) appended to the name of a railway indicates that a statement in regard to that railway will be found in the original report of 1890.—E. E. R. T.

SECTION 1.—EUROPE.

ENGLAND.

GENERAL REMARKS.—Very little progress has been made since 1890. One railway finds metal ties a failure, another is extending its experiments, while a third (with 56 miles of steel ties) is not laying any more. It must be remembered that the standard type of track has creosoted ties with double-headed rails carried in chairs having a wide base, so that both decay and wear of the tie are provided against, while metal ties (according to experience here and elsewhere) give better results where T-rails are laid directly upon them than where these large chairs are interposed to carry double-headed rails. On the other hand, the manufacture of cast-iron and steel ties for export is a very important industry. One firm alone had, up to 1892, manufactured 2,800,000 steel ties (representing 130,000 tons) and could turn out meter gauge ties at the rate of ten per minute. The prejudices of the trackmen against metal ties are referred to under the head of "Tracklaying" in Part II.

Summary of metal track in England.

	Miles.
Great Eastern Railway	2.50
London and Northwestern Railway	56
Metropolitan Railway	7.25
Midland Railway	2.50
Northeastern Railway	5
Total in 1894	73.25
Total in 1890	70

GREAT EASTERN RAILWAY* (gauge, 4 feet 8½ inches).—When in Europe in 1890 I saw a number of the steel trough ties (referred to in my original report), with cast-iron chairs for bull-headed rails, which had been taken out and stacked beside the track at a point near London, where extensive alterations were in progress, but I was informed by Mr. John Wilson, the chief engineer, that they had not been abandoned, but were to be put down again. Further particulars have been promised, but not received. These ties were of inverted trough section, 13 inches wide over the bottom, 9½ inches wide on top (between the intersections of lines of sides and top), $3\frac{7}{16}$ inches deep, ¼ inch thick, with top corners $2\frac{1}{16}$ inches radius. They had at each end four holes for the vertical ends of the two "twin" or U-bolts attaching each chair. the bolt heads being united by a strip or leg which bears on the inside of the top of the tie. The ties weighed only 80 pounds each, and were made in 1887. The experience with them has been too short to allow of any definite conclusions. The wooden ties are of creosoted Baltic pine, 10 by 5 inches section and 8 feet 11 inches long, weighing about 138.6 pounds. The maintenance expense during 1890, including renewals on a considerable length of the line, was 6.7 cents per train mile.

LONDON AND NORTHWESTERN RAILWAY* (gauge, 4 feet 8½ inches).—Mr. F. W. Webb, the mechanical superintendent, of whose rolled-steel ties 100,085 were in use on 56 miles of track in 1889, wrote me in May, 1894, that at present the use of the steel ties is not being extended, He thinks that in some cases they have been found rather light for the work on this road, and his own experience shows that their efficiency depends a good deal upon the kind of ballast in which they are laid. These ties have been tried (with the English bullheaded rails) on the Pennsylvania Railroad. (*See* United States.)

In July, 1894, Mr. Harry Footner, engineer of permanent way, sent the following particulars, from which it may be inferred that the Webb ties have not proved very satisfactory:

> Of 100,000 metal sleepers laid down between the years 1880 and 1890 there have been 17,700 taken up. Of these, over 1,380 have been repaired and laid in yards or where trains do not run at high speed, and the remainder have been scrapped. The average life of the sleepers taken up from the main lines was 6 years 11 months, and the average life of the sleepers still in the main line is 7 years 4 months. This company has not laid any metal sleepers since 1888 and has no present intention of putting down any more.

These ties were rolled in a three-roll mill from ingots of Bessemer steel. The rivet holes were punched hot at one stroke so as to insure their exact relation to each other and make an accurate fit in riveting. The punches were conical and the holes made so that the smaller diameters came together, thus securing tight riveting. Later the ties were made from Thomas-Gilchrist steel, which was said to be better dephosphorized, softer, and less liable to crack. In 1886 the weight was given as follows, being ten pounds lighter than in 1890:

	Pounds.
Tie 9 feet long	123.86
2 chairs	27.94
Rivets	5.06
2 base plates	14.96
2 wooden keys	1.98
Total	173.80

The cost in 1886 was $2.42, of which 12 cents were for labor; while the wooden ties, with chairs, etc., cost as follows:

Tie	$0.98
2 chairs	.73
Fastenings	.33
Total	2.04

METROPOLITAN RAILWAY * (gauge, 4 feet 8½ inches wide).—Ties of mild steel have for some years been used on the St. Johns Wood line, and are of shallow trough section, with the upper surface sloped down at the ends. They are about 8 feet 4 inches long, 8¼ inches wide on top, 13¼ inches wide over the bottom flanges, 3 inches deep, and three-eighths inch thick. They weigh 145 pounds each, and to prevent rusting are dipped in a bath of tar at 94° C. The ordinary chairs for bull-head rails are used, each chair fastened to the tie by four seven-eighths inch bolts, with necks seven-eighths inch square and one-fourth inch deep, fitting into square-punched holes in the ties to prevent the bolts from turning. The bolts have hemispherical heads. Steel ties are also used on the extension between Northwood and Rickmansworth, and between Amersham and Aylesbury, on the Aylesbury extension. The following statement was furnished me in April, 1894, by Mr. John Bell, the general manager:

> About 3¼ miles of double road (track) were laid with metal sleepers in September, 1887, and 4 miles of double road in September, 1892. The sleepers were made by Bolckow, Vaughan & Co., and are of trough section, with the ends flattened. The sleepers are of steel, laid upon gravel ballast. The permanent way is composed of the usual Metropolitan Railway pattern rails and chairs. The latter are bolted to the sleepers by four seven-eighths-inch bolts, a felt pad being interposed between the base of the chair and the sleeper. The road laid with these sleepers is more difficult to keep, both in line and level, than the ordinary wooden-sleeper road, more especially on curves.

MIDLAND RAILWAY * (gauge, 4 feet 8½ inches).—In April, 1894, Mr. J. A. McDonald, chief engineer, wrote me as follows:

> We laid down 5 miles of steel sleepers as an experiment, and more than half have had to be taken out before they had been in use seven years. These metal sleepers cost about four times as much as timber sleepers, and the result has been thoroughly unsatisfactory.

A statement made in June, 1889, by Mr. A. Langley (then chief engineer), and published in my original report (p. 66), was to the effect that the steel ties had proved efficient in service and that the maintenance was practically the same as with creosoted wood ties. The ties were of trough section with cast-iron chairs weighing 40 pounds bolted to them and carrying bullheaded rails.

NORTHEASTERN RAILWAY* (gauge, 4 feet 8½ inches).—The pressed steel ties of the Cabry pattern are made from plates 8 feet long and 16 inches wide. The rail clamps punched up from the plate leave the backs corrugated or buckled so as to increase the stiffness. (*See* Part II, "Fastenings.") The Riley tie has also been tried. In this tie the metal of the top table is folded to form a seat embracing the inner side of the rail flange and bearing against the web, while the outer side forms a jaw between which and the rail web a wooden block or "key" is driven. It was invented in 1887 by Mr. Riley, of the Steel Company of Scotland. (*See* "Riley tie.")

NORTH STAFFORDSHIRE RAILWAY * (gauge, 4 feet 8½ inches).—In my former report mention was made of the placing of a large order for steel ties, but Mr. G. J. Crosbie-Dawson, chief engineer, wrote me in April, 1894, stating that the order was not executed, as, owing to the advance in prices of iron and steel, the makers wanted a higher price per ton than they originally asked when their offer was accepted. The few ties already in service have been taken up owing to alterations in the station yard where they were laid. In September, 1894, however, the Chair and Sleeper Company stated that the ties at Stoke, on this road, were still in use and a few months previously were found to be as good as ever and had not been touched since they were laid, some years ago. The engineer's statement is undoubtedly the most accurate. The tie is of V-section with horizontal top flanges and is patented in this country (No. 430552).

TIES.

Hudson tie.—The tie made by R. Hudson, Gildersome foundry, near Leeds, for portable railways, is composed of two flat disks connected by a tie bar, alternate ties having lugs to fit the inside and outside of the rail.

Ker tie.—The "elastic" tie, patented by Thomas Ker, M. Inst. C. E., and exhibited at the Edinburgh Exhibition in 1890, is made from a long steel plate, the middle portion, about 8 feet 6 inches long, being of shallow trough section, while the parts beyond this are flattened out to full width and bent downward and then upward and back under the body of the tie, closing the bottom of the trough and having the end riveted to the top of the tie near the middle. The top table is thus not supported on the ballast. The end loops are several inches deep to afford resistance to lateral motion. For flange or tee rails lugs are stamped up out of the tie and horizontal wedges driven between the lug and rail base. Chairs for double-headed rails can also be secured by clamps and keys. The weight is estimated at 65 pounds for meter gauge, 128 pounds for standard gauge, and 136 pounds for 5 feet 6 inches gauge, the chairs weighing 25 pounds each in addition. The idea of the design, as stated by the inventor, is to cause a spring or elastic action of the upper part while the lower portion takes its support on the ballast.

Riley tie.—A somewhat interesting form of tie is that invented by Mr. Riley, of the Steel Company of Scotland, in 1885, and used to some extent on the Northeastern

Railway. It is a trough tie (as shown on Pl. No. 32), and in rolling the metal is left thicker at the rail seats than at other parts, and by pressing the ends of the plate together the jaws are formed. Both the inner and outer jaws or lugs are first pressed into the form of a high jaw with vertical face to the rail and inclined back, the height being from base of rail to underside of head. The inner jaw is then pressed or folded in to fit over the rail flange and bear against the web of the rail. A wooden key is driven between the outer jaw and the web of the rail, the tie being adapted for rails of either **T** or double-head section. The inner jaw is forced into shape by the use of special dies. If the metal is of sufficiently mild quality and worked only at a proper heat the ties may be successfully made, but it would appear that unless these conditions were rigidly adhered to, the amount of strain set up by cold working would be such as to cause the number of rejected or spoiled ties to be very great.

White tie.—A tie made from old mining rails of Ω or brige section was designed by Mr. J. W. White, of Widnes, in 1893, and is intended mainly for narrow-gauge, colliery, and mining tracks. The rail is cut into lengths of 3 feet, each forming a tie. The rail is inverted, and two clip chairs are placed in the channel thus formed, each secured by a key or bolt. The hollow of the track rail (also of bridge section) fits over a lug on the chair, while a lug on the outer edge of the chair holds the rail by its flange. (*See also* the "North Staffordshire Railway.")

FRANCE.

General Remarks.—The extended tests on the state railways have given good results, both in efficiency and economy, under heavy and fast traffic, as shown by the official statements from Mr. Bricka, engineer in chief, whose early investigations and valuable report (issued in 1884) were referred to at some length in my original report. He now has 115 miles of metal track, as against 31 miles at the end of 1889. Some other roads have instituted or continued experiments, while one has removed the metal ties from its main tracks, owing to their weakness. However, as the creosoted beech ties on this latter road last about twenty-seven years, there is little incentive to use the more expensive metal ties.

Summary of metal track in France.

	Miles.
Belt Railway, Paris	0.06
Eastern Railway	0.05
Northern Railway	0.00
Paris, Lyons, and Mediterranean Railway	2.73
State Railways	115.00
Western Railways	3.25
Paris Street Railway	2.30
Tours and Vouvray Steam Tramway	4.41
Total in 1894	127.80
Total in 1890	52.12

Belt Railway of Paris (gauge, 4 feet 8½ inches).—In August, 1888, there were laid 105 steel ties of the Boyenval-Ponsard type (*see* "France" and also Pl. 6 of former report) on a length of 315 feet of track. They were 8 feet 3 inches long, weighing 140 pounds, and had base plates for T-rails weighing 74 pounds per yard. The fastenings were screw spikes, screwed into wooden blocks in the channel of the tie. These ties were laid on a curve at the Est-Ceinture station, at a point where the Westinghouse brakes are applied to stop the trains, and they were put in to replace wooden ties without interfering with the traffic. They carry sometimes 300 trains daily, but the attachments keep tight and the ties have not shifted their position. In April, 1894, Ponsard & Co., of Paris, wrote me as follows:

> We especially call your attention to the ties laid on the Belt Railway of Paris, which have been in service since December, 1888, and have carried a traffic of 241,000 trains, the greater part of which has been heavy freight trains, without showing the slightest alteration. The number of trains represents for a railway of light traffic, with 20 trains per day, a life of thirty-three years. The better to inform you as to the value of our system of metal tie, we have thought it would be useful to take out of the track two ties, one joint tie and one intermediate tie, in order to report to you as to how our ties behave under such traffic. We are happy to tell you that these two ties are in a perfect state of preservation, and that it is impossible to predict when they will be out of service. We do not doubt that the ties now in the track can support the passage of four or five times the number of trains noted above before they will require to be renewed.

EASTERN RAILWAY* (gauge, 4 feet 8½ inches).—In July, 1884, the chief engineer sent me a statement in regard to the experience with the Guillaume and Post steel ties, which were laid in 1886, but only on a limited scale. The former were taken out in 1891, and the latter are found to be too weak for the traffic. The official statement is as follows:

> We have laid only 100 of the Guillaume ties, 100 of the Post ties, and immediately at the side 100 ordinary creosoted oak ties, for comparison. The rails are of steel, 39.36 feet long, weighing 60 pounds per yard, and having 16 ties to a rail length. The joints are broken and suspended. The track was partly on tangent and partly on a curve of 3,600 feet radius. The number of trains was about 25,000 per year, and toward the end of the experiment it was about 30,000. The fast trains make about 50 miles per hour. The heaviest load on one axle of the engines is 16¼ tons. The Guillaume ties were taken out of the track about the beginning of 1891, after having been subjected to a traffic of 130,000 trains. The Post ties and the creosoted oak ties are still in the track, and have carried about 210,000 trains.
>
> *Guillaume steel ties.*—The keys (or bearing blocks), of compressed elm, had to be renewed in 1889, after three years' service. They wore to the surfaces of contact of the rails and ties, and have thus prevented the wear of the clamps and the rail flange at the clamps. A certain number of the clamps broke. The ballasting behaved well enough as long as the keys remained intact.
>
> *Post steel ties.*—The attachments have behaved well so far. Their wear is insignificant, and does not exceed half a millimeter at their contact with the rails and ties. The gauge is not widened on the curve, but is narrowed about 5 millimeters (0.2 inch) on the tangent. Although the ties weigh 169¼ pounds, they bend lengthwise, the middle becoming depressed about 10 millimeters (0.4 inch) below normal level. It is necessary to tamp them several times every year, as the ballast is very permeable. These results go to show that the section of the ties is too weak for the traffic they have to carry.
>
> *Creosoted oak ties.*—None of the ties have had to be replaced for any defect whatever. A plate of tarred felt is placed between the tie and the rail, which prevents the wear of the surfaces in contact. This lasts about three years. The track maintains always its proper gauge and the inclination of the rails. The stability of these ties is superior to that of the Post ties, and they require less maintenance.

NORTHERN RAILWAY* (gauge, 4 feet 8½ inches).—This road has made some trials with metal ties, but the results were not satisfactory, and the ties were removed from the main tracks and placed in the yards. More than twenty years ago a trial was made with 5,000 Vautherin ties, but they could not be kept in position in the ballast, and the attachments were unsatisfactory, while in case of derailment there was great delay in repairing the track. In 1885 there were 1,500 Severac ties laid on the company's Belgian lines (*see* Belgium). In 1888 between 7,000 and 8,000 Severac ties (*see* Pl. 10 of original report) were laid at different points in France on sections where the traffic was heavy and at high speeds, which proved the weakness of the ties. The shocks to the rail attachments by fast trains broke the keys and gradually loosened the rivets attaching the tie plate to the I-beam forming the tie. All these ties have been taken out of the main tracks. The details of weight were as follows:

	Pounds.
I-beam, iron	88.66
Rivets, iron	1.10
Base plates, iron	11.00
End plates, steel	48.84
Keys, steel	1.54
Total	151.14

The wooden ties are mostly of beech, creosoted by the Blyth process, with 28.6 pounds of creosote per tie. They are 10.4 by 5.2 inches section and 8 feet 6 inches long, weighing (after treatment) about 189.2 pounds. A small number of oak ties are used, weighing about 198 pounds. The average life of the ties is twenty-seven years, and therefore they are naturally considered superior to the metal ties which have been tried.

PARIS, LYONS, AND MEDITERRANEAN RAILWAY* (gauge, 4 feet 8½ inches).—In April, 1894, Mr. Michel, chief engineer of permanent way, wrote me that 6,300 metal ties were laid in 1891 on two sections of the line, as follows: 2,750 ties on 1.46 miles of the Valence and Moirans division, and 3,550 on 1.27 miles of the branch from Toulon to Hyeres. The former have carried 17,000 trains and the latter 15,000 trains, and all are in good condition. The ties are of Vautherin section, as used on the company's lines in Algeria (*see* Pl. 17 of my original report), but the vertical key or cotter has a sharper taper. The weight of the tie is 33.6 pounds per yard, and the weight of tie and attachments is as follows:

Parts.	Pounds.
1 tie	96.80
2 gibs, outside, 0.725 pounds each	1.45
2 gibs, inside, 0.660 pound each	1.32
2 cotters or keys, 1.078 pounds each	2.15
2 gibs at back of cotters, 0.330 pound each	0.66
9 Total	102.38

The Merans system and Brunon system were tried experimentally several years ago. (*See* Appendix 1, "Historical Notes.")

STATE RAILWAYS* (gauge, 4 feet 8½ inches).—Very careful observations of the results of the metal ties in use on these lines have been kept by the engineers, and I am indebted to Mr. Bricka, chief engineer, for copies of the tabular statements prepared for presentation at the fifth meeting of the International Railway Congress, to be held in London, in June, 1895. As stated in my original report, three types of ties are being tried (*see* p. 79 and Pls. 5 and 6 of that report), namely: (1) the Paulet and Lavalette ties, with double-headed rails; (2) the Vautherin tie of uniform section, with double-headed rails; and (3) the Vautherin tie of varying section, with flange, or T-rails. The length of track laid with these ties May 1, 1894, is given below, and aggregated 115 miles:

Section of railway.	(1) Paulet and Lavalette.	(2) Vautherin (uniform).	(3) Vautherin (variable).
	Miles.	*Miles.*	*Miles.*
(A) Between Airvault and St. Loup	2.10		
(B) Between Chartres and Bron		6.15	
(C) Between Chartres and Bron			4.46
(D) La Roche-sur-Yon to Bressuire			4.59
(E) La Roche-sur-Yon to Bressuire		12	
(F) Niort to La Rochelle		2.75	
(G) La Rochelle to Rochefort		16.72	
(H) Montreuil-Bellay to Angers		15.89	
(I) Loudun to Montreuil-Bellay		13.63	
(J) Ambares to Bordeaux		14.53	
(K) La Roche-sur-Yon to Lucon		22.21	
Total	2.10	103.88	9.05

1. *Paulet and Lavalette ties.—A. Airvault to St. Loup.*—These ties are composed of chairs (for 76-pound double-headed rails) fixed between the vertical webs of two angle-irons by means of four rivets. The two joint ties are connected by riveted angle-irons, and on curves the track is almost entirely laid with ties thus connected. The ties are 7.54 feet long, 8.2 inches wide, composed of angle-irons 3.6 by 2.8 inches. The ordinary ties weigh 165 pounds; double joint ties, 290 pounds; and double intermediate ties, 301.4 pounds. There are 3,700 ties in use, spaced about 34.6 inches center to center, and they have been in service five years without deterioration and without one having been replaced. The cost of maintenance per mile per annum has been as follows, the materials being exclusive of ballast for retamping, none of which, however, has been required:

	1891.		1892.		1893.	
	Metal.	Wood.	Metal.	Wood.	Metal.	Wood.
Labor	$27.50	$73.50	$41.8	$52.90	$19.50	$21.18
Materials		32.45		47.20	0.58	26.35
Total	27.50	105.95	41.8	100.10	20.08	47.53

The wooden ties on this section are of oak, not treated, 8.53 feet long, 10 by 6 inches section, weighing 165 pounds, and are spaced 24 inches at the joints and 39.2 inches intermediate. There are 3,700 ties, which have been in use seven years, the renewals being 79 ties in 1891, 93 ties in 1892, and 50 ties in 1893. The reason for renewal was that the wood no longer held the rail attachments well. No special difference has been noted between the two types of track, but it is seen that the cost of maintenance will show a more important difference for 1894 and 1895, the cost with wooden ties having been as given above. This section, having an equal number of metal and wooden ties, is in a variable temperate climate, with little snow. All curves are of 1,640 feet radius, their total development being 1.55 miles. The rails are the same and the ballast is of 3-inch broken stone. The traffic averages 3,640 trains per year (exclusive of work trains), running at speeds of 15 to 40 miles per hour, and hauled by engines weighing 33 to 53 tons on a wheel-base of 35 to 37 feet (including the tender).

2. *Vautherin ties of uniform section, with double-headed rails.*—This type of metal track is used on a number of sections, as shown by the foregoing table, and has been found very efficient and decidedly economical in maintenance expenses, which economy is found to increase steadily. The ties make a smooth and easy riding track, do not show any signs of corrosion or wear, and do not cause any extra wear of the rolling stock, while the bolted fastenings are reported as being perfectly satisfactory, and the permanence of the track is particularly commented upon. It would occupy too much space to go into the details of each section, especially as on some of these the experience has been too short to allow of any definite results being observed, but I have taken notes from the reports of some of the sections, and in order to facilitate comparison I have given more fully the report of the section from Chartres to Bron (B), as on this section there are 7,848 wooden ties, 7,750 metal ties of the type mentioned in the heading (type 2), and 7,848 metal ties of type 3, described farther on.

B. Chartres to Bron.—The ties are of steel, of trough section, with ribs on the bottom edges. They are 8.2 feet long and 10.12 inches wide, weighing 129 pounds, while the fastenings weigh 2 pounds. There are 7,750 of these ties, which were laid in the early part of 1887. Longitudinal cracks between the bolt holes, showing an injury to the metal by punching, have been observed in three ties, one of which has been removed. The track is as elastic as that on wooden ties and the difference can not be perceived by passengers, and safety of operation is assured, while the ties have proved satisfactory on grades and curves. The attachments with chairs and keys gives good results, and there is no indication of wear of the bolts or holes. The cost of maintenance per mile per annum for metal and wooden ties has been as follows, the materials being exclusive of new ballast, none having been required:

	1890.			1391.			1892.			1893.		
	Metal.		Wood.	Metal.		Wood.	Metal.		Wood.	Metal.		Wood.
	Type 2.	Type 3.		Type 2.	Type 3.		Type 2.	Type 3.		Type 2.	Type 3.	
Labor........	$67.74	$45.15	$61.29	$66.13	$48.39	$64.51	$64.51	$48.39	$69.35	$48.39	$29.03	$38.71
Materials....	4.84	1.61	4.84	4.84	1.61	4.84	4.84	1.61	4.84	4.84	1.61	4.84
Total..	72.58	46.76	66.13	70.97	50.00	69.35	69.35	50.00	74.19	53.23	30.64	43.55

The wooden ties are of oak, 8.53 feet long, 8.8 by 6 inches section, and weighing 176 pounds, while the rail attachments weigh 2 pounds. They were laid in 1887, at the same time as the metal ties, and none have been renewed. The climate is mild, with cold winters and heavy rains in the autumn. The rails are of double-headed section, weighing 76 pounds per yard (except that 78-pound T-rails are used on metal ties of type 3), and all the ties are laid in a ballast of silicious sand, having about 40 per cent of broken stone. The traffic is about 8,000 trains per annum, weighing 150 to 350 tons, and hauled at speeds of 15 to 55 miles per hour by locomotives weighing 48 to 68 tons, on a wheel-base of 35 to 37 feet (including the tender).

(E) *La Roche-sur-Yon to Bressuire.*—The metal ties manufactured in 1888 by the Denain-Anzin Works are 8.2 feet long, 4.8 inches wide on top, 9.2 to 10.1 inches wide on the bottom, 0.32 inch thick, and weigh 127.6 pounds. The chairs weigh 23 pounds each and the keys are of oak or steel. The rails are 36 feet long and weigh 76 pounds per yard. The ties are spaced 39.2 inches apart and 24 inches at the joints. The ballast is of 2½-inch broken stone and sand. There are 20,469 of these ties (laid in 1888), and 22,943 nonimpregnated oak ties (laid in 1887), weighing 154 pounds, both carrying about 5,700 trains per annum, of 90 to 350 tons train load. The cost for labor for maintenance per mile per annum for the years 1891–'92–'93 has been $58.71 for the metal and $61.93 for the wooden ties; while the cost for material (exclusive of ballast, none required) increased from $1.29 to $1.93 for the metal, and from $2.26 to $2.58 for the wooden ties. In regard to this section, it is noted that while the track on wooden ties had, undoubtedly, during the first year, a marked advantage over that on metal ties in elasticity and consequent comfort to passengers and preservation of rolling stock, yet it tends now to rapidly lose that superiority. This is due to the perfect maintenance of the metal track, which has become almost as elastic as the other, and it appears to be an indisputable fact that while the former is more difficult to maintain during the first year, it ends by attaining a remarkable degree of stability when the ballast has thoroughly filled all voids, preserving absolute rigidity of the fastenings, while with wooden ties, however carefully maintained, dislocation of the attachments becomes evident in about five years.

(G) *La Rochelle to Rochefort.*—There are 21,108 steel ties, weighing 125½ pounds, and 12,432 impregnated oak ties, 8.86 feet long, 10 by 6.4 inches section, weighing 187 pounds. They all carry 76 pound rails, are spaced 24 and 39.2 inches at joints and intermediates, and are laid in ballast of quarry sand. The metal ties have been in service one year, and carry 5,000 trains per year, while the wooden ties have been in service ten years and carry 4,000 trains per year. Both tracks are elastic and easy riding, but the wooden ties in broken-stone ballast wore more rapidly than those in sand.

(H) *Montreuil-Bellay to Angers.*—There are 10,920 ties of mild steel, 8.2 feet long, weighing 125½ pounds, with bolts 0.86 pound, and chairs 23 pounds each. These have been in service 2 years. There are also 1,970 treated pine ties and nontreated oak ties on curves, 8.36 feet long, 10 by 6 inches section, weighing 198 and 165 pounds each. These have been in service seven years. The rails weigh 76 pounds per yard, and the ballast is of sand and gravel, slightly earthy. The ties are spaced as above. The traffic is about 5,700 trains per year. The cost of maintenance per mile per annum is about $130 for labor for both wood and metal ties, and $9.16 and $4, respectively, for material, while the expense is expected to be still more favorable to the metal ties after 1894.

(J) *Ambares to Bordeaux.*—There are 14,200 ties of mild steel, weighing 130 pounds, with 47.7 pounds extra for fastenings. These have been in service two years. There are also 21,800 nontreated oak ties, 8.53 feet long, 8.8 by 6 inches section, weighing 154 pounds, which have been in service seven years. The rails weigh 76 pounds per yard, the ballast is of sand and gravel, and the ties are spaced as in section G. The traffic is 5,000 trains per year. The cost of maintenance for the metal ties for labor only, in 1892 (their first year), was $124.58 per mile, while that for the wooden ties had increased in that year to $261.11 for labor, $7.60 for materials, and $9.06 for ballast for retamping.

3. Vautherin ties of variable section, with flange rails.—This type of track is of more special interest, in view of the fact that the rails used are of the type exclusively used in the United States, and, as already shown in the table under type 2, section B, the cost of maintenance with this track has been less than that of track with similar ties and double-headed rails or of wooden ties with double-headed rails.

C. Chartres to Bron.—There are 7,848 ties of mild steel, 8.53 feet long, 10.82 inches wide, weighing 124.3 pounds, with 1.43 pounds extra for the fastenings. They were laid in 1887. The rails are of flange or T-section, weighing 78 pounds per yard. The bolted clamp fastenings give good results and show no wear, but with gib and cotter fastenings there is a little wear of the rail flange, but the holes in the ties show no wear. It is, however, said to be difficult to maintain perfect line and surface with these rails on metal ties. Longitudinal cracks between the bolt holes, proving bad punching, have been observed in 42 ties, but none of these ties have been renewed. The track is said to ride harder and to be more noisy than that on wooden ties. The cost of maintenance has been given in a previous table.

Boyenval and Ponsard ties.—In addition to the ties above mentioned, Ponsard & Co., of Paris, state that 260 of the Boyenval-Ponsard ties were laid early in 1888, some near Bailleau le Pin and others at La Roche-sur-Yon, covering a length of 780 feet, and spaced 3 feet apart. The former are for 76-pound double-head rails with cast-iron chairs, and these are 8.2 feet long, weighing 112 pounds each, or 171 pounds with the chairs. The others have base plates for 70-pound T-rails, are 8.2 feet long, and weigh 132 pounds each, with plates and fastenings. All have closed ends. The tamping is easily effected, and in February, 1890, Mr. Bricka, the chief engineer, certified that the ties were behaving well.

Z-bar ties.—Some of these ties (*see* Belgium) are said to have been tried.

In the discussion of the subject of metal ties at the meeting of the International Railway Congress at St. Petersburg, in 1892, Mr. Bricka stated that the use of these ties on the state railways of France had been commenced in 1887, and in consequence of the satisfactory results their use had been extended until at that time they had been laid for 68¼ miles. The greater part of this length had double-headed rails in cast-iron chairs, and it had been predicted that many of the chairs would break, but as a matter of fact there were fewer broken chairs on the metal ties than on wooden ties. His experience did not agree with that of the Belgian state railways, the officers of which consider the metal ties as unsuitable under high-speed traffic, as on the French lines the ties behave perfectly at points where trains run regularly at speeds of 43 to 50 miles per hour, although these ties are lighter than the Belgian ties, weighing only 127.6 pounds. His practice in comparing the cost of maintenance is to take lengths of track sufficiently long to include the sections of one or more track gangs, and to take into account all the expenses of labor of the regular and extra gangs. In regard to the number of men on the section gangs he gave the following very interesting figures, giving the number of men on sections where the track has been in service at least two years, and including not only the section men, but those working in the station yards, at fences, etc., and, in general, all those on maintenance and repairs not requiring special workmen, such as masons, blacksmiths, etc.

(1) Line from Paris to Niort and Bordeaux, between Chartres and Bron: Number of trains, 8,584 per year, or about 23 per day; maximum grade, 0.15 per cent; minimum radius of curve, 1,640 feet; average speed of fast trains, 40 miles per hour.

(*a*) Metal ties with double-head rails in cast-iron chairs, laid in January, 1887; length, 4.5 miles. On this length is also the La Faye station, with 8 switches and 0.79 mile of sidetrack on wooden ties. From January, 1887, to January, 1891, there have been 5 men, or, say, 1 man to 0.9 mile. Since January, 1891, only 4 men, or, say, 1 man to 1.12 miles. Since January, 1887, there have been only 176 days of extra men who have been employed to raise the ballast, etc.

(*b*) Post's steel ties with T-rails, laid in March, 1887; length, 4.9 miles. On this length are the stations of Bailleau le Pin and Magny, with 9 switches and 1.05 miles of track on wooden ties. Up to August 31, 1890, there were 5 men; to December 31, 1890, 4 men; and since January 1, 1891, only 3 men, or, say, 1 man to 0.98, 1.22, and 1.6 miles. No extra men have been employed.

(2) Line from Sables d'Olonne to Tours, between Bressuire and Chantonnay: Number of trains, 4,145 per year, or about 11 per day; grade, curvature, and speed as above.

(*c*) Metal ties with double-head rails in cast-iron chairs, laid in June, 1888; length, 12 miles. On this length are the stations at St. Mesmin, Ceritzay, and Clatzay, with 18 switches and 1.56 miles of track on wooden ties. The number of men has been as follows:

	Miles.
June, 1888, to June, 1889, 14 men, or 1 man to	0.86
June, 1889, to March, 1890, 8 men, or 1 man to	1.50
March, 1890, to 1892, 7 men, or 1 man to	1.70

The extra labor has amounted to 966 days, or 19 days per mile per year. There has also been spent on drainage works and reballasting $656, or $13 per mile per year.

(*d*) Post's steel ties with T-rails, laid in 1887; length, 4.61 miles. On this section there are no switches or sidetracks. The number of men has been as follows:

	Miles.
January, 1887 to March, 1889, 4 men, or 1 man to	1.15
March, 1889, to June, 1890, 5 men, or 1 man to	0.92
June, 1890, to 1892, 3 men, or 1 man to	1.54

The iron rails were replaced with steel rails in March, 1891, and in 1892 there were spent $331.60 for renewing rail clamps on account of the play of the attachments. There has been no extra labor.

These results are very satisfactory, and while they are nearly approached by the results with track on wooden ties under similar conditions, there is, nevertheless, an advantage on the side of the metal ties, and this will increase as the age of the wooden ties approaches ten years, as they will then require respiking, adzing of the seats, etc.

WESTERN RAILWAY* (gauge, 4 feet 8½ inches).—It was stated in my original report (p. 89) that the metal ties used on this line had been designed and made by Mr. Chappee, of Mans, but I am informed by the director of works of the railway and also by Mr. Chappee, that the ties were designed by Mr. Bouisson, engineer of the railway, and that Mr. Chappee cast the chair (according to the plans prepared in the railway company's offices) upon the steel channel bars sent to him, the bars being rolled at thes Ibergues works.

In December, 1889, the company laid 5,000 ties of this type on 3.10 miles of the line from Viroflay to Mans, the ties differing slightly from those laid in 1887. In the later ties the channel bar is not sharp-cornered, as shown on Plate 7 of the original report, but has corners of 0.68 inch radius, not concentric, giving a thickness of 0.45 inch at the corner, 0.32 inch on top, and 0.3 inch at the lower edges of the sides. The depth is 3.2 inches, with the chairs projecting 1.6 inches below. The tie is 8.2 feet long and 8 inches wide over the channel. This bar weighs 127.6 pounds and the two castings 124.5 pounds, or 252.1 pounds in all. There are 10 ties to a rail 26.24 feet long, and with suspended joints the joint ties are spaced 24 inches center to center, the next ties 28.8 inches, and the intermediate ties 34 inches. The rails are of double-headed section, weighing 77.5 pounds per yard. The ballast is of sand mixed with round pebbles, and the ties are laid on curves and grades, on one track of a double-track line. There are about 30 passenger and freight trains per day on each track, the speed varying from 18.6 to 49.5 miles per hour, and the maximum train load being 400 tons with 40 four-wheeled cars. The heaviest engines (which have trucks like American engines) weigh about 105,600 pounds without the tenders, which weigh 60,500 pounds. The wheel-base is 24.4 feet.

In June, 1894, the following official statement was furnished, signed by the director of works and by Mr. A. Bouisson, engineer of material:

> The Western Railway metal channel ties in service on the line from Viroflay to Mans number 5,000. They were placed in December, 1889, between kilometers 158.78 and 163.78 (a distance of 3.10 miles) on the down line near the station of Theil. A first inspection, made in 1891, showed that the ballast maintained itself badly in the interior of the channel between the rail chairs and the ends of the ties. To remedy this inconvenience, 50 of the ties were closed at each end by means of an iron plate bent in channel shape, with its sides riveted to the flanges of the channel of the tie. This modification was completed in December, 1891. A new inspection of these ties, made during the month of May, 1894, has resulted in the following observations:
>
> The chairs cast on the tie remain firmly attached, and there is no play between the casting and the channel iron. There is no trace of oxidization or deterioration of the channel iron. The track is in very good condition and is in perfect alignment. There has not been any sensible difference observed between this track and the track laid with wooden ties, except that there is a vibration of the ballast at the ends of the ties not closed at the ends. The appearance of the track where the ties have closed ends is exactly the same as that with wooden ties. The ballasting is generally good, the ballast being very compact and well packed under the tie. Of two ties taken out for examination, the one with closed ends had the ballast tightly compacted between the flanges of the tie, forming a solid mass; while in the tie with open ends, the ends were empty for a distance of about 4 to 4½ inches. The trackmen state that the ties with closed ends are as stable as the wooden ties.
>
> The maintenance expenses tend to diminish year by year. The table gives the expense per mile each year on the down line laid with metal ties and on the corresponding part of the up line laid with wooden ties, showing that the maintenance of the former for the last two years was about 10 to 12 per cent more expensive than that of the latter. The renewals have been on account of the fracture of the jaws of the chairs (holding the rails):

Year.	Metal. ties.	Wooden ties.	Excess for metal ties.	Number of metal ties renewed.
1890	$158.06	$70.97	$87.09	26
1891	90.32	61.29	29.03	5
1892	67.74	61.29	6.45	0
1893	87.09	77.42	9.67	0
Total				31

A similar arrangement of tie was invented in England in 1863 by the Rev. Osborne Reynold, as noted in Appendix 1, " Historical Notes."

ANTZIN MINES (gauge, 4 feet 8½ inches).—On the railway at the Antzin mines there are 150 Boyenval-Ponsard steel ties, 8 feet 3 inches long, with base plates for T-rails, and weighing 140 pounds each, including attachments. They were laid in 1888 on a length of 450 feet.

PARIS STREET RAILWAY (gauge, 4 feet 8½ inches).—The Compagnie Générale des Omnibus de Paris, in 1892, laid 4,000 of the Boyenval-Ponsard steel ties, weighing 50 pounds each, on a length of 2 miles 1,500 feet.

TOURS AND VOUVRAY STEAM TRAMWAY (gauge, 4 feet 8½ inches).—This line has 7,750 Boyenval-Ponsard steel ties, 5 feet 6½ inches long, and weighing 61 pounds each, including the base plates for the Broca grooved rails. They were laid in 1889 on a length of 4 miles 2,250 feet.

TIES.

Boyenval-Ponsard ties.—These steel double-channel ties were described in full in my original report (p. 84 and Pl. 6), and have since then been introduced in several countries, as shown by the following table, for which I am indebted to Ponsard & Co., of Paris. The tie is patented in this country (U. S. patent No. 496133). Further particulars of the several lines will be found in their respective places. The 900,000 ties for the French-Algerian Railway are to be laid in replacing wooden ties during six years, and the makers are also negotiating for the supply of 1,200,000 ties for the East Algerian Railway, to be laid in the same manner. Exclusive of these items the table may be summarized as follows:

	Number of railways.	Number of ties.	Length of track.	
			Miles.	*Feet.*
Europe (France, Greece)	6	39,965	23	15
Africa (Algeria, Soudan, Kongo, Senegal, Egypt)	6	177,250	101	1,270
Asia (China, Tonkin)	2	4,252	2	2,316
South America (Argentine Republic, Brazil)	4	77,037	43	4,671
West Indies (Porto Rico, San Domingo, Martinique)	3	357,000	204	2,250
Total	21	655,504	374	5,242

The following table gives a detailed list of railways using these ties:

Boyenval-Ponsard steel ties.

Country.	Railway.	Gauge.		Number of ties.	Weight.	Length of track		Date when laid.
		Ft.	*In.*		*Pounds.*	*Miles.*	*Feet.*	
France	State railways	4	8½	260	140		780	1887
Algeria	Bône-Guelma Rwy	4	8½	2,500	127	1	2,550	1888
Do.	West Algerian Rwy	4	8½	250	140		750	1888
Senegal	Dakar-St. Louis Rwy	3	3⅜	52,000	80	30	0	1888
France	Antzin Mines	4	8½	150	140		450	1888
Do	Belt Rwy., Paris	4	8½	105	140		315	1888
China	Port Arthur Rwy	3	3⅜	4,200	70	2	2,160	1889
Argentina	(Not stated)	4	8½	4,500	93	2	3,000	1889
Soudan	Kayes-Bafoulabe Rwy	3	3⅜	3,000	55	1	1,750	1889
France	Tours-Vouvray	4	8½	7,750	61	4	2,250	1889
Kongo	Belgian-Kongo Rwy	2	6	112,000	70	64	0	1889
Porto Rico	Porto Rico Rwy	3	3⅜	330,000	50	189	0	1890
San Domingo	Central Dominican Rwy	2	6	25,000	66	14	1,500	1890
Greece	Diacophto-Kalavryta Rwy	2	6	27,700	23	16	0	1890
Argentina	(Not stated)	4	8½	8,037	66	4	3,111	1891
Brazil	Central Brazil Rwy	3	3⅜	25,000	75	14	1,500	1891
Do	do	5	3	38,000	106	21	3,120	1891
France	Co. Gen. des O. de Paris	4	8½	4,000	50	2	1.500	1892
Brazil	Paulista Rwy	3	3⅜	750	75		2.250	1893
Do	do	5	3	750	106		2,250	1893
Martinique		3	9	2,000	55	1	750	1893
Tonkin	Hanoi Tramways	3	3⅜	52	57		156	1893
Egypt	Alexandria and Cairo Rwy	4	8½	7,500	167	4	1,500	1894
Algeria	French-Algerian Rwy	3	6	900,000	89	500	0	1894
	Total *			655,504		374	5,242	

* Exclusive of the last-named railway, on which the ties are to be laid in annual renewals during six years.

Dufour tie.—This is a steel tie of trough or channel section, with rail fastenings consisting of angle bars about 3 or 4 inches long. The edge of the flange of the bar is bent down in a hook shape, and passes through a hole in the tie, the hook end bearing upon the under surface of the tie. A bolt passes through the angle bars and the web of the rail.

HOLLAND.

General Remarks.—The Netherlands State Railways, on which the well-known Post steel tie has been very extensively used, has abandoned the further use of such ties, not, however, on account of failure of the ties, but for financial reasons. The operating company leases the railways belonging to the state, and as the latter has the right to assume control at any time, the company naturally does not feel warranted in making heavy improvement expenditures to obtain an eventual economy of which it may not reap the benefit.

Summary of metal track in Holland.

	Miles.
Dutch Central Railway (1885)	4.88
Dutch-Rhenish Railway (1885)	64.48
Holland Railway (1891)	112.00
Netherlands State Railways (1894)	100.00
Total for 1894	322.36
Total for 1890	321.36

HOLLAND RAILWAY* (gauge, 4 feet 8½ inches).—The double-track line from Amsterdam to Winterswyk has a length of 2.6 miles with 4,827 ties. The track is laid with oak and red-pine ties, 8.4 by 6 inches section and 8 feet 6 inches long, weighing 187 pounds and 154 pounds, respectively. These ties are impregnated with chloride of zinc under a pressure of 60 pounds per square inch, the solution containing 40 parts of water to 1 part of chloride of zinc of 4° Beaume. The other track is laid with mild-steel ties, 8 feet 6 inches long, 2.6 inches deep, the joint-ties (with level surface and inclined base plates) weighing 110 pounds, and the intermediate ties (bent to give the inclination to the rail) 85 pounds. The rails weigh 76 pounds per yard and the fastenings are of gibs and vertical cotters (as in Pl. 17 of my original report) on the intermediate ties, and bolted clamps on the joint ties. The intermediate ties are spaced 3 feet apart and the joint ties 22.6 inches. The ballast is of sand. On this section there are 24 passenger trains (including 11 expresses) and 13 freight trains daily. The express trains weigh about 200 tons and have a speed of 43 to 50 miles per hour; the ordinary passenger trains, 60 tons and 25 miles; the freight trains, 800 tons and 16 miles. The heaviest load per axle of the locomotives is 14 tons. The average annual expense during the period of 1888 to 1890 was $146.77 per mile for the track with wooden ties, and $219.35 for that with metal ties. The deterioration of the metal ties consisted principally in cracks at the rail seat, resulting from the hammering of the rail and in wear of the fastenings occasioned by the track being out of line. The ties were considered to be too light, too thin, and too shallow, and the fastenings too weak. Since 1876 the company has laid 112 miles with metal ties, but since 1891 has abandoned them and decided to replace them with wooden ties.

NETHERLANDS STATE RAILWAYS* (gauge, 4 feet 8½ inches).—In my original report was given a table (p. 97) of the cost for maintenance on the different divisions having metal ties, and I give below the additional figures for 1888, 1889, and 1890, as presented at the International Railway Congress in 1892, and also for 1891, 1892, and 1893, as sent to me by the chief engineer for the purpose of this report. The following is a summary of the information presented at the congress in regard to the comparison of wooden ties and Post's steel ties (types Nos. VIII and IX, *see* Pl. 8 of the original report) on two new sections of the Eindhoven-Achel division of the Liege and Limbourg line. The trial included 1,120 wooden ties, 93 steel ties of No. VIII section, and 93 of No. IX section. The ties were spaced 2 feet apart at joints and 3 feet intermediate. Many of the wooden ties broke, owing to their being too thin, and many of the spikes were also broken. With the metal ties there were no breakages, but some cracks occurred at the bolt holes, and the fastenings were not considered sufficient on curves. The wear of the bolt holes caused a slight widening of the gauge, which did not occur with ties having a cast iron tie plate between the rail and the tie. The bolts kept tight. The ties were of mild steel, 0.36 to 0.44 inch thick under the rail, and weighed 117.7 to 118.7, which was considered sufficient for such a line with moderate traffic. The heaviest engines weigh 51 tons on 4 axles, with a wheel-base of 23 feet; the greatest load per axle being 15 tons. The regular maximum speed is 46 miles per hour. The defects above-mentioned have been recognized for some years, and on the divisions with the heaviest traffic, such as the Venlo-Flessingen line, there was also wear of the metal by the flange of the rail. On tangents this wear was under the inner edge of the rail flange, causing a tightness of gauge, while on curves it was under the outside edge, causing a slack gauge. The ballast was of poor quality, mainly sand of different degrees of coarseness, and it was pointed out that metal ties require good ballast (coarse gravel or broken stone), and also that the thickness of ballast should be greater than for wooden ties. A modified and heavier form of tie is now being tried, weighing about 132 pounds, and having a double ridge on the underside (pl. 9 of original report), which stiffens the tie and within which fit the bolt-heads. A few hundred ties of this type have also been fitted with stamped-iron chairs, the weight, including chairs, being 163 pounds. These ties have drilled instead of punched holes.

While awaiting the results of the tests of these Post steel ties of modified form the management has provisionally adopted for its main lines pine ties impregnated with chloride of zinc and then creosoted (to keep the zinc from washing out). The rails rest on steel tie-plates and are secured to the ties by clamps and screw spikes. The Post tie-plates, with flat bottoms and with toothed bottoms, have been used extensively.

In July, 1894, Mr. Kalff, chief engineer of permanent way, sent me a statement showing that the further use of metal ties has been abandoned, not on account of failure of the ties, but because the economy due to their use is only realized by reason of their long life, and as the Government can at any time exercise the right to take over the railways from the "Company for the Operation of the Netherlands State Railways" (which leases the railway from the Government), it is natural that the company should be disinclined to make expenditures to obtain an economy which may be enjoyed only by the Government. The statement is as follows:

> We must inform you that we have now quite abandoned the extension of the use of metal sleepers. We doubt whether metal sleepers are to be considered as most fitted for our railways, the roadbed being often of a marshy nature and the ballast being sandy. But even if this doubt did not exist, the heavy outlays for a more costly construction of the permanent way (which outlays are only to be reimbursed by a longer duration of that more costly construction) do not agree with our present lease of the State railways, as that lease is only temporary, and as the contract authorizes the Government to, at any time, take the operation of these railways into its own hands, the possibility exists that the heavy outlays would only benefit the State and be only a loss to the company.

We use now impregnated wooden ties, with flat-bottomed tie-plates, the rails and plates being fastened to the ties by screw spikes. (*See* Part III of this report—E. E. R. T.). The toothed-bottom tie-plates have only been used for a very short time and are not used any more. They destroyed the ties and were a complete failure. As to the results of our experience with the metal sleepers, we refer to our notes published in the reports of the meetings of the International Railway Congress at Paris, September 14 to 23, 1889 (Vol. II, Question VII, Letter C, Annex A), and at St. Petersburg in August and September, 1892 (Vol. I, Question VIII, Letter B, Note III). As a continuation of the latter we send you a table giving the amount of maintenance work of the 27 sections during the years 1891, 1892, and 1893. To this we may add that the metal ties with drilled holes give much better results than those with punched holes.

Cost of maintenance on trial tracks with wooden and with metal ties, Netherlands State Railways Company.

Division.	Cost of maintenance per day per kilometer.				Ties broken.	Clamps broken.	Bolts broken.	Bolts worn and loosened.	Cost of maintenance per day per kilometer.			Year when laid.
	1887.	1888.	1889.	1890.					1891.	1892.	1893.	
	Fr'cs.	*Fr'cs.*	*Fr'cs.*	*Fr'cs.*					*Fr'cs.*	*Fr'cs.*	*Fr'cs.*	
Liege-Tongres (wood)*	0.423	0.273	0.769	0.835	†600	‡614	......	......	0.537	0.861	0.884	1881
Do	.842	.452	.582	.473	9	3	1,594	6,694	3.027	1.166	.642	1881
Bilsen-Hasselt	1.135	2.020	1.526	.631	....	7	158	5,123	.960	1.578	.316	1881
Liege-Tongres	.552	1.499	1.140	.125	....	11	66	2,705	.293	1.469	1.166	1882
Liers-Flémalle	.573	1.340	2.617	.912	41	49	279	2,568	2.011	1.802	1.958	1882
Tongres-Bilsen	.046	.268	2.487	.280	....	46	7	824	.907	1.254	.351	1882
Bilsen-Hasselt	.623	.923	2.593	1.155	....	31	711	1,666	1.200	1.110	.385	1882
Liege-Tongres	......	......	......	......	....	....	......	......	......	......	......	1883
Do	......	......	.709	.125	....	....	......	1	.255	.583	.292	1889
Do	.746	.534	1.533	.598	....	37	54	621	.567	.794	.328	1883
Do	1.610	1.511	1.047	.185	....	3	323	9,656	.822	.677	1.277	1883
Do	1.000	.472	.730	.798	....	....	30	972	.270	.853	.423	1883
Do	.893	1.690	......	Nil.	....	....	168	1,974	.768	3.721	2.668	1885
Do	......	.398	.162	.097	....	....	97	7,377	.948	.238	.474	1887
Liers-Flémalle	......	2.240	.424	1.470	....	....	7	156	4.712	None	1.896	1886
Do	......	1.217	......	1.653	....	....	......	145	3.556	None	2.889	1886
Hasselt-Wijchmael	.297	.487	.680	.281	....	....	146	192	.372	.886	.548	1881
Wijchmael-Achel	.227	.346	1.190	.256	....	1	234	169	.730	.717	.618	1881
Hasselt-Wijchmael	.595	.511	.964	.625	....	36	13	614	.293	.517	.421	1882
Do	.583	.470	1.225	.231	2	14	41	98	.331	.416	.636	1883
Do	.429	.842	.553	.226	....	10	356	116	.945	1.744	.334	1883
Achel-Eindhoven	.802	.263	1.161	.351	....	2	7	318	.096	.325	.502	1883
Do	.651	.498	.447	.096	....	6	14	188	.616	.691	.550	1884
Do	.492	.186	.492	.398	....	....	35	352	1.493	.531	.494	1884
Do	.252	.841	.946	.297	....	....	31	271	.052	.560	.327	1885-'86
Do	......	.694	.075	.412	....	....	......	12	None	.562	.986	1887
Do	......	.666	.007	.414	....	....	......	......	.081	1.126	.705	1887

* Wooden ties. † Broken ties. ‡ Broken spikes.

TIES.

Post ties.—The inventor of these well-known ties having been in the Dutch East Indies since 1890, he has not kept himself well informed as to the experience of roads using these ties, but writing in April, 1894, from Java, he stated that probably about 1,500,000 of the Post ties (with thickened rail seats and inclination of 1 in 20 given to the rail seat directly in the rolling of the tie, as described in my former report) are now laid in Europe, Asia, South Africa, and the Argentine Republic. The Sumatra State Railway (3 feet 6 inches gauge), in operation since 1891-'92, is laid entirely with these ties, but they have punched instead of drilled holes. They are giving excellent service. The improvement of drilling instead of punching the holes has been introduced since 1889, and is expected to have a favorable influence on the life of the ties, owing to the reduced liability of cracks starting at the bolt holes. The Post ties with drilled holes have been laid on the lines of the Dutch South African Railway, in the Transvaal Republic, and on the lines of the Netherlands State Railways. The ties tried on the Eastern Railway of France were found to bend under traffic, not being stiff enough to carry the traffic to which they were subjected.

BELGIUM.

General Remarks.—On the State Railways metal ties are not regarded with favor, although extensive experiments have been made. A great increase in cost of maintenance over that for track on wooden ties is reported, while the unsatisfactory results are also said to be due to the high speed traffic. The evidence in this direction, however, is by no means conclusive, since in other countries a reduction in maintenance expenses has been observed, even where there is a fast and heavy traffic. The excessive weight of these Belgian ties has been commented upon in my original report. The Great Central Railway has had continued satisfactory experience with its metal ties, which are of wrought iron instead of the more usual mild steel, and similar experience has attended the use of steel ties on light railways or steam tramways.

Summary of Metal Track in Belgium.

	Miles.
Belgian State Railways (1893)	155.60
Great Central Railway (1892)	5.56
Taviers and Embresin Railway (1894)	6.25
Local Railways (Charleroi) (1891)	8.99
Total for 1894	176.40
Total for 1890	115.50

Belgian State Railways * (gauge, 4 feet 8½ inches).—During my visit to Europe in 1890 I was enabled, through the courtesy of the engineers, to examine the steel ties near Antwerp. The Bernard ties had already been taken out, and some of the Post ties (laid in 1886) were being taken out, the principal defect being that they cracked at the corners of the bolt holes, an objection which Mr. Post has avoided in his later ties by the use of circular holes, with ribs on the underside of the tie to fit the square heads of the bolts and prevent them from turning, as stated on page 101 of the original report. In the storage yard at Antwerp were a number of steel ties with a crack at the middle, starting from the lower edge and running up the side. This was explained as being due to defects in the metal. It was also objected that the ballast (small broken stone) compacted to such an extent as to hold the water and be pulverized or gradually churned into mud. On the whole, the engineers were not favorably disposed toward the metal ties, but my observation was that they made a very easy riding track, with less pounding of the joints, due probably to the security of the bolt fastenings. In 1892 Mr. Janssen, one of the engineers, published a statement making a very unfavorable showing for the metal ties. This statement gave a summary of five years' experience with the Braet and Post ties, both weighing 165 pounds, but having different forms of cross section. There were 12 ties to a rail length of 29 feet 6 inches, and the rails (weighing 76.6 pounds per yard) were fastened to the ties by clamps and bolts. Observations were made on 4 sections of track with metal ties and 1 section with half-round creosoted oak ties. It was found very difficult to keep the metal tie track in good condition, particularly as the stone ballast became pulverized by the ties, so that new ballast had to be added in 1891. The ties showed cracks at the bolt holes, and out of 240 ties of each type that were carefully examined 77.5 per cent of the Braet ties and 17.9 per cent of the Post ties were more or less cracked. Up to the time of Mr. Janssen's statement the track with metal ties had cost for maintenance about 19 times as much as the track with oak ties, while many of the metal ties were damaged to such an extent that they would soon have to be renewed. These figures, however, can not be taken as conclusive evidence against metal ties, as quite opposite results are reported from other roads, while the accuracy of Mr. Janssen's figures (given in the following table) has been called in question, as shown in the paragraph on the Emperor Ferdinand's Northern Railway (Austria) on another page.

Type of tie.	Length of section.	Hours labor per year per mile.		New material per year per mile.		Cubic yards stone ballast added, 1891, per mile.	Cost of maintenance per year per mile.
		Surfacing, etc.	Tightening bolts.	Bolts.	Spring washers.		
	Feet.						
Post	4,396	4,266	519	310	1,147	1,570	$453.80
Braet	6,792	3,114	504	347	1,179	1,626	420.80
Post	3,619	4,140	446	252	1,052	1,526	447.10
Braet	3,183	2,949	502	333	1,164	1,153	462.80
Oak	2,697	466	....	76	....	....	23.15
Total	20,687	....	....	....	....	....	....

Labor at 4.64 cents per hour. Bolts at 2.63 cents per pound. Ballast at 74 cents per cubic yard. Washers at 4.39 cents per pound.

The wooden ties used are of half-round section with seats adzed out by hand for the steel tie-plates, but rectangular ties are used at frogs and switches. Belgian oak is preferred, being very hard. It comes principally from Luxembourg, but only a third of the quantity required can be obtained thence and no reforestation is provided for. American and Prussian oak are considered to be grown too fast in high country, with the result that the texture is not close and the wood is too soft. Holes are bored through the ties of the diameter of the beveled end of the round spikes, and the ties do not split in spiking. With new track the spikes will begin to draw out after a while, but when once redriven they remain firm. Screw spikes are also used for the Goliath rails of Sandberg section, weighing 104 pounds per yard. Creosoted oak ties, impregnated with 3½ to 4 gallons of creosote per tie, cost about $1.10, while steel ties cost nearly twice as much in 1885 when steel was cheap. The ballast is of broken stone, in some places small and in others coarse. The wear of rails is found to be about the same on steel and wooden ties.

In June, 1894, Mr. De Busschere, engineer in chief, furnished the following statement:

We have now no more of the Vautherin and Rhenish types of metal ties on our trunk lines. They have all been removed on secondary branch lines, on sidings, and in the yard tracks of our large stations, and also in the shops and locomotive sheds. As stated in your interesting report of 1890, we laid in 1885 and 1886, on our main trunk lines, 17.67 miles with ties of the Post system, 16.12 miles with ties of the Braet system, and 3.4 miles with ties of the Bernard system. The Bernard ties are condemned and have all been removed except for a length of 330 feet on a down grade of 1.66 per cent, where they have behaved well; but on all the other sections many failures have been recorded. The ties of the Post and Braet types, when laid on lines with heavy and rapid traffic, show many breakages at the holes for the rail fastenings. The number of ties of these two types actually taken out of the main track on account of defects is as follows:

(1) Between Louvain and Liege. The 1,345 Braet ties laid in 1886 had supported, before removal. 110,000 trains, the daily traffic on that line in each direction consisting of 28 freight trains, 20 passenger trains, and 10 express trains, some of them running at speeds of 50 to 58 miles per hour.

(2) Between Brussels and Antwerp. In 1886 there were laid on the down line (with a descending grade of 1 in 500) 3,256 Post ties and 867 Braet ties, while 3,194 Braet ties were laid on the up line. These ties have supported 300,000 trains, the daily service in each direction being 30 freight trains, 60 passenger trains, and 15 express trains.

At the same time I received from the engineer in chief of permanent way and works the following statement, together with a table showing the number of ties still in service on March 31, 1893:

The Hilf longitudinals, tried on a large scale in 1876 and 1877, have given poor results in the track. The joints of the longitudinals do not correspond with the center lines of the cross ties placed under their ends; the rails crept or shifted on the longitudinals; the track became loose and shifted, and the longitudinals cracked. These defects being rapidly increased it became necessary to take up this track on the main lines and to place it in sidings and yard tracks. The Serres and Battig longitudinals did not give any better results, and the rails of special section broke. The Vautherin ties laid in 1879, under important traffic, will not give any more satisfactory results. It was soon seen that these ties were too light; cracks started at the rail flanges, the fastenings were insecure, the track rattled and became loose, and the maintenance became very difficult. At the end of a few years it was necessary to take them out almost entirely from main tracks with important and fast traffic.

During 1886 the administration put in service the metal ties of the Bernard, Post, and Braet systems. The former have been rapidly taken out, their failure being attributed by the inventor to the quality of metal. The Post and Braet ties are still, for the most part, in the track, but a large number of them have cracks, especially at the angles of the holes for the bolts which attach the rails to the ties. The passage of trains over these ties is considered to be more noisy than over wooden ties, but not so much so as to annoy the passengers. The maintenance on the main lines is much heavier for the metal ties than for the wooden ties.

Metal ties laid and in service on the Belgian state railways.

Systems of track.	Date laid.	Length of single track.		
		Length laid.	Remaining in service on Mar. 31, 1893.	
			Main tracks.	Other tracks.
		Miles, feet.	*Miles, feet.*	*Miles, feet.*
Hilf longitudinals (with cross-ties)	1876 1877	31 162½ 46 3,736½	1,155	62 4,090
Total	......	77 3,899	....	....
Serres & Battig longitudinals (with cross-ties)	1878	3,280	33	2,014
Soignies ties	1878	1 345	1,696	1,489
Vautherin ties*	1879	64 1,642 29 4,297	28 2,705	26 4,833
Total	......	95 4,284	28 4,434	27 3,111
Post ties (A)†	1886	17 3,884‡	17 1,952	1,817
Braet ties (B)§	1886	16 1,620	15 4,860	800
Bernard ties (C)‖	1886	3 2,610	3,601	1 4,121
Total	......	37 2,834	33 5,133	2 1,458
Grand total	......	211 457	63 162	92 3,380
			155 miles 3,542 feet.	

*88.37 pounds per tie.

† Netherlands state railways type, 165 pounds per tie.

‡ Of these, 2,300 ties are taken from the Liege and Luxembourg Railway, weighing 110 pounds each.

§ 165 pounds.

‖ 231 pounds

NOTE.—On January 1, 1893, there were in the storehouses the following materials, which the division engineers have been requested to utilize as far as possible, except the pieces reserved for maintenance: Hilf longitudinals, 1 mile 1,920 feet; metal ties previous to 1886, 17 miles 2,500 feet; Braet ties, 1,850 feet, or 19 miles 990 feet of single track.

The Belgian state railways have adopted for trunk lines the "Goliath" rail, 104 pounds per yard (modified by Mr. Flamache from the Sandberg section), and this is laid on 744 miles, replacing a 76-pound rail, which is laid on lines with heavy and express traffic, but not carrying the international express trains. The ties are of oak, creosoted by contract, with about 2 gallons of creosote per tie. They are all of half round section, and 8 feet 6 inches long. Those under the 104-pound rails are 11 inches wide on the bottom and 5.6 inches thick, while those under the 76-pound rails are 10½ inches wide on the bottom and 5.2 inches thick. They cost about $1.12 each, creosoted, and are estimated to last ten or twelve years under heavy traffic, after which they will last another ten years at least in less important track. They are all protected by tie plates, except the joint ties of the 104-pound rails, on which the heavy flanges of the angle bars take a bearing, and are secured by screw spikes. The tie-plates under these rails are grooved, and have three holes for screw spikes. They are 9.6 by 5.2 inches, and 0.56 inch thick under the rail. The spikes are 6.8 inches long over all, 0.64 inch diameter in the shank, with a coarsely pitched thread, and have circular heads 2.4 inches diameter (with a square projection for the track wrench), which bear directly on the rail flange and the rib of the tie plate. There are 8 ties under a rail 13.68 feet long, and 12 under a rail 29.52 feet long, spaced 24 inches at the suspended joints, 28 inches at the shoulders, and 32 inches intermediate. The 76-pound rails have flat tie plates one-half inch thick; those at the joints are 6.8 by 7.4 inches, with square holes for four spikes, and those on the intermediate ties are 4 by 8 inches with two spike holes. There are 12 ties to a rail 29.52 feet long.

Great Central Railway * (gauge, 4 feet 8½ inches).—A statement respecting the experience on this road was presented at the International Railway Congress in 1892. There are 11,624 metal ties and 887,394 nonimpregnated oak ties from the Ardennes on the 494 miles comprising this system. The metal ties are of the J. B. Caramin type, of approximately semicircular section, with flattened top and horizontal bottom flanges. (*See* Plate No. 11 of original report.) The ties and riveted washers are of iron, and the tie plates and screws of steel. Bessemer steel rails of flange section are used, weighing 76 and 70 pounds per yard, and also 68 pound bullheaded rails for branches. The joint ties are spaced 24 inches center to center, the shoulder ties 36.8 inches, and the intermediate ties 37.6 inches. The ballast is of washed gravel, river gravel, stone broken to a 2.4-inch ring, and engine cinders, the three latter being used for the metal ties. The average annual traffic for the years 1881 to 1890, inclusive, was 2,429 passenger trains (aggregating 634,983 tons) at 37 miles per hour, 655 mixed trains (74,078 tons) at 28 miles per hour, and 2,270 freight trains (5,105,000 tons), at 16 miles per hour. The heaviest engines weigh 52.3 tons on a wheel base of 14 feet. The ties were laid on 2.5 miles in 1886, 3 miles in 1887, and 0.6 mile in 1888. The average annual expense for maintenance of track on wooden ties during the years 1881 to 1890 was $161.87 per mile (including bolting, tightening fastenings, lining, etc., and replacing ties, rails, and track material). The average annual expense of the track with metal ties during the years 1886 to 1890 was $20.16, which was very low, because the bolts kept tight, the track remained in line, and there were no renewals of rails, ties, or material. No defects had been observed in the metal or manufacture, or in the attachments. The track on wooden ties is more elastic than that on metal ties but there is no inconvenience to passengers, and no difference in wear of rolling stock has been observed.

Northern Railway * (gauge, 4 feet 8½ inches).—The returns made by the Northern Railway of France for the International Railway Congress of 1892 in regard to the 1,500 Severac ties laid on its Belgian lines in 1885, stated that they had behaved well during about four years, but had been taken up after the gauge of track had been sensibly widened by the wear of the flange of the rail against the lug of the tie plate.

Taviers and Embresin Railway (gauge, 2 feet 4 inches).—This is a local railway 6¼ miles long, laid with 28-pound T-rails 29 feet 6 inches long. The ties are made from old rails. Each tie consists of two pieces of rail 4 feet 11 inches long and about 6 inches apart, with two wrought-iron chairs, the top of the chair resting upon the rails and forming the rail seat, while a hollow projection beneath fits the outlines of the head, web, and base of the rails. A long rivet passes through each chair and the webs of the tie rails. The track rails are secured by clamps and vertical bolts. On tangents there are four ties to a rail length, and on curves nine ties, while tie bars or bridle rods assist to maintain the gauge on curves. Each tie weighs 46⅓ pounds, and each chair weighs 8.8 pounds. The rails are laid with supported joints. The ballast is of broken stone and cinders 10 inches deep. There are about twenty trains a day, and the speed is slow. The track was laid in 1887.

LOCAL RAILWAYS * (gauge, 3 feet 3⅜ inches).—The Société Anonymes des Railways Economiques, which owns local railways in different parts of Belgium, has three lines near Charleroi. These lines run to Mont sur Marchienne, 1.86 miles; to Lodelinsart, 2.17 miles; and to Martigny le Tilleul, 4.96 miles. The first has a curve of 115 feet radius on a grade of 2 per cent, and has other grades of 3.8 and 4.7 per cent. The second has curves of 82 to 115 feet radius and grades of 3.2 to 5.5 per cent. The third has curves of 82 feet to 102 feet radius, and grades of 3 to 4.7 per cent. The first two lines have each one train in service, making 15 trips each way per day. The third line has three trains in service, making 30 trips each way per day. The lines are all of meter gauge and are laid with flange rails on the Z-bar ties, invented by Mr. Willemin, of Brussels, and manufactured by the Société Anonyme de Marcinelle et Couillet at the Couillet works. (*See* Pl. 10 of original report.) In paved streets the rails weigh 60.3 pounds per yard, and are the height of the paving blocks. Where the line is laid along the side of country roads the rails weigh 43.2 pounds per yard, and the ties are bedded in cinder ballast. Mr. Laviollette, the director, had the ballast dug up on a part of the track that had not been disturbed for three years, and I found the ties in good condition, with the iron key fastenings perfectly tight. Each tie consists of two steel Z-bars, 5.9 feet long, forming a channel 4 inches, open on top, the width over the top flanges being 10 inches. Two chairs are placed inside the channel and each secured by three long rivets passing through the bars and chair. Two taper keys form the rail fastenings. Each tie weighs 115 pounds complete, or 194 pounds when filled with ballast. Wooden ties are used at switches and crossings, but on a new line then under construction it was intended to use long Z-bar ties. There are nine steam tramway engines, or "dummy" engines, weighing 15 tons empty and 17.5 tons in working order. They have horizontal outside cylinders 11.28 by 14.8 inches, and are carried on six wheels, all coupled, 32 inches diameter and 36 inches center to center of axles, giving a wheel base of 6 feet. The cars are like street cars, 15.75 feet long over the body and 22.3 to 23.6 feet long over the buffers. They weigh about 3 tons empty and are carried on four wheels 24 inches diameter, with a wheel base of 6 feet. They have seating capacity for 20 to 24 passengers. The maximum speed authorized is 12.4 miles per hour.

In a report made by the Société Nationale des Chemins de Fer Vicinaux à Bruxelles and presented at the meeting of the International Tramway Union in August, 1894, it was stated that after seven years' service they had been found badly corroded by rust, while the fastenings were defective. They were therefore being replaced with the creosoted oak ties as used on the other lines of this company.

TIES.

Angleur ties.—The Angleur Steel Works roll various sections of ties, using Thomas basic steel of 88 to 99 pounds per square millimeter, and 25 to 20 per cent elongation in 8 inches.

Z-bar ties.—These ties have been described in the original report, and some further details respecting those on the local railways of Charleroi are given under that heading. The weight of the iron chairs has been reduced by Mr. Willemin, the inventor, by making them from Swedish cast iron by a new patented process, the metal being known as mitis metal, which is claimed to be superior to and cheaper than wrought iron. It is of great strength, enabling the weight of the chair to be reduced to two-thirds that of the former chairs. In 1890 I visited the great ironworks of the Société Couillet, at Couillet, Belgium, to see the manufacture of the Z-bar ties for the narrow-gauge Kongo Railway. The tie is composed of two wrought-iron bars of Z or double-angle sections, the top flanges being outward and the lower ones inward, while the web is vertical. They thus form a box or trough, open on top and nearly closed on the bottom. Near each end of the tie is a cast-iron chair resting inside the trough, projecting a little above the top of the tie and forming a seat for the rail, having lugs to hold the flange of the rail. Each chair is secured by two (or for large ties three) long horizontal rivets passing right through the tie. The riveting was done by hand, but I was informed that if large orders were given a power riveting plant would be erected. The ties for the Kongo Railway weighed about 70 pounds complete, but when in the track and packed with ballast the weight would be about 90 pounds. The ballast was to be of broken stone, obtained from some heavy cuts on the line. One of the special advantages claimed for this type of tie is that of economy in weight of metal combined with ample weight when in the track and filled with ballast. The fastening of the rail is very simple, consisting merely of a slightly tapered key. The rail is placed on the chair, with one side of the base held by the lug of the chair, and the key is then driven between the rail base and lug on the other side of the rail. The direction for driving the key is indicated by an arrow cast on the lug, so that the work can easily be done by unskilled labor. In keying up a light hand hammer is used, as the use of a sledge hammer would result in breaking off the lugs. Ties of this type can be made for use at switches and cross-overs, and the bars may be of wrought iron or steel, the former being used for the Kongo Railway ties, as it was then as good as and cheaper than steel in Belgium. These Z-bar ties are in use on the following railways: State railways, France; local railways (Charleroi), Belgium; Royal Portuguese Railway, Portugal; Minho and Douro Railway, Portugal; Southern and Southeastern Railway, Portugal; Egyptian railways, Egypt; Bone-Guelma Railway, Algeria; Loanda and Ambaca Railway, Kongo (Portuguese); Kongo Railway, Kongo (Free State).

GERMANY.

General Remarks.—In this country a large and steady increase in the mileage of track laid with metal cross-ties is to be noted, as shown in the following tables, and very favorable results in efficiency and economy are reported. The use of metal longitudinals is decreasing, however, and two railways which have furnished statements for this report mention the abandonment of the metal longitudinal system. The Baden State railways, the Hesse-Louis Railway, and the Elberfeld Division of the Prussian State railways are among those which have found them unsatisfactory. On the other hand, the Haarman "self-bearing" (or girder) rail, which forms a longitudinal in itself, is meeting with some favor, but the principle of such a track is quite different from that of a track having ordinary rails attached to longitudinals or stringers.

As this report is intended to be mainly supplementary to the original report, I have not attempted to give in detail the progress on each of the numerous railways, as formerly, but merely to show the general growth of the metal-track system. The conditions may be summarized as follows, the figures being for ordinary railways only, and exclusive of local and narrow-gauge lines, inclined railways, etc.:

	1891-'92.	1888.
Track with—	*Miles.*	*Miles.*
Metal cross-ties	8,025	5,224
Metal longitudinals and self-bearing rails	3,580	3,562
Wooden ties	33,985	32,147
Stone ties or supports	272	356
Total length of track *	45,960	41,291

* There is an inconsiderable difference between the added totals and the official totals.

From the official report on the railways of the German Empire for the year 1891-'92 I take the following statistics with reference to the tracks, the statistics referring only to the standard gauge railways:

Length of track:		
State railways	miles..	42,149
Private railways	do....	3,811
Total	do....	45,960
Length of railways:		
State	do....	2,378
Private	do....	2,456
Total	do....	68
(A) Rails without ties:		
Iron	do....	10
Steel	do....	58

(A) Rails without ties:		
State railways	miles	53
Private railways	do	15
Total	do	68
Prussian State railways	do	18
Würtemberg State railways	do	12½
(B) Compound rails	do	3⅖
(C) Longitudinals (Hilf, etc.):		
Iron	do	286
Steel	do	3, 294
State railways	do	3, 438
Private railways	do	142
Total	do	3, 580
Prussian State railways	do	2, 432
Weight per mile:		
With cross-tie connections	tons	105
Without cross-tie connections	do	82
(D) Cross-ties (wood):		
Wooden ties		60, 761, 049
Per mile of track		1, 787
Oak:		
Treated		19, 043, 798
Untreated		10, 508, 148
Other hard woods:		
Treated		2, 236, 866
Untreated		108, 563
Coniferous (pine, larch, and spruce):		
Treated		27, 365, 360
Untreated		1, 498, 314
(E) Cross-ties (metal):		
Number		14, 531, 617
Per mile of track		1, 811
Average weight per tie	pounds	110
(F) Stone blocks:		
Number		721, 078
Per mile of track		2, 645

Of the compound rails (B) there are 2.78 miles of the Scheffler system on the Magdeburg Division of the Prussian State railways and 0.62 mile of the Kostlin and Battig system on the Saxony State railways. None were laid during the year 1891–'92.

The next table gives particulars of the distribution of ties. Of the 22 divisions of the Prussian State railways, five have no metal ties, and on the others the distribution is as given in column No. 1, the figures being for open track only, and not including ash pits, etc., where the rails are laid on masonry walls. Of 19 other State railways only 6 have no metal ties, so that out of 41 State railways 30 have metal ties, and the distribution on these 30 lines is given in column No. 2. On the private railways (those owned by companies) the track laid with cross-ties has 74 per cent of wood, 25 per cent of metal, and 1 per cent of stone. Column No. 3 shows the distribution for the State and private railways.

Distribution of cross-ties, 1891-'92.

	No. 1.	No. 2.		No. 3.	
	17 Prussian State railways.	41 German State railways.		State and private railways.	
	Miles.	*Miles.*	*Per cent of track.*	*Miles.*	*Per cent of track.*
Total track	28, 895	......	......	......	......
On wooden ties	21, 419	31, 253	80⅓	33, 985	80⅓
On metal ties	4, 934	7, 121	19	8, 025	19
On stone	68	262	⅔	272	⅔
Total	26, 441	38, 658	100	42, 308	100

A general summary of the distribution of ties on all German railways is given in the following table:

	Total track.	Cross-ties.							
		Wood.		Metal.		Stone.		Total.	
	Miles.	*Miles.*	*P. ct.*	*Miles.*	*P. ct.*	*Miles.*	*P. ct.*	*Miles.*	*P. ct.*
Prussian State railways and those managed on State account	28, 895	21, 419	81	4, 934	19	68	......	26, 441	100
Prussian private railways	1, 257	872	74	316	25	......	1	1, 191	100
All German State railways	42, 150	31, 254	80⅓	7, 122	19	262	⅔	38, 658	100
All German private railways	3, 810	2, 731	74½	903	25	16	½	3, 650	100
Total, all German railways	45, 960	33, 985	80½	8, 025	19	272	½	42, 308	100

The long table which follows shows the miles of track of different kinds on each of the German railways for the years 1890 and 1891, with the increase or decrease in each case, the totals indicating a decrease in the mileage of double-headed rails, metal longitudinals, and stone supports, and an increase in the mileage of metal cross-ties:

Track of German railways.

Railways.	Double-head rails on wood ties.			Flange rails on wood ties.			Stone supports.		
	1890.	1891.	Increase (+) or decrease (—).	1890.	1891.	Increase (+) or decrease (—).	1890.	1891.	Increase (+) or decrease (—).
	Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*
Alsace-Lorraine	29. 76	26. 66	—3. 10	737. 80	781. 82	+44. 02	......	......	......
Baden State	......	......	......	824. 60	752. 06	—72. 54	2. 48	2. 48	......
Bavarian State	47. 12	48. 98	+1. 86	3, 336. 84	3, 441. 62	+104. 78	188. 48	186. 14	—2. 34
Hesse-Louis	......	......	......	374. 48	372. 00	—2. 48	1. 86	1. 86	......
Hessian State	......	......	......	148. 18	148. 80	+0. 62	......	......	......
Lubeck and Buchen	......	......	......	114. 08	112. 84	—1. 24	0. 62	0. 62	......
Luxembourg	1. 24	1. 24	......	118. 42	119. 04	+0. 62	......	......	......
Main-Neckar	......	......	......	88. 04	84. 94	—3. 10	......	......	......
Marienburg	......	......	......	106. 64	106. 02	—0. 62	0. 62	0. 62	......
Mecklenburg State	17. 36	17. 98	+0. 62	518. 94	520. 80	+1. 86	0. 62	0. 62	......
North German	......	......	......	92. 38	92. 38	......	......	......	......
Oldenburg State	......	......	......	319. 30	318. 06	—1. 24	......	......	......
Palatinate	......	......	......	759. 50	741. 52	—17. 98	2. 48	2. 48	......

Track of German railways—Continued.

Railways.	Double-head rails on wood ties.			Flange rails on wood ties.			Stone supports.		
	1890.	1891.	Increase (+) or decrease (—).	1890.	1891.	Increase (+) or decrease. (—).	1890.	1891.	Increase (+) or decrease (—).
	Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*
Prussian State:									
Altona	1.86	1.86		1,588.44	1,634.94	+46.50	2.48	2.48	
Berlin				2,677.16	2,775.74	+98.58	11.16	11.16	
Breslau				2,585.40	2,755.90	+170.50	9.30	9.30	
Bromberg				3,732.40	3,922.12	+189.72	1.34	0.62	—0.62
Cologne (left bank)	1.24	1.24		823.36	744.00	—79,36	8.06	8.06	
Cologne (right bank)				1,949.28	1,906.50	—42.78			
Elberfeld				476.78	435.24	—41.54	5.58	5.58	
Erfurt	6.82	4.34	—2.40	1,688.88	1,697.56	+8.68	1.86	2.48	+0.62
Frankfort	6.82	6.20	—0.62	916.36	936.20	+19.84	4.34	4.34	
Hanover	0.62	0.62		2,277.88	2,341.74	+63.86	5.58	5.58	
Magdeburg	362.08	329.22	32.86	1,860.00	1,921.38	+61.38	1.24	0.62	—0.62
Saxony State				2,611.44	2,626.32	+14.88	8.06	8.06	
Southeast Prussia				156.24	157.48	+1.24	0.62	0.62	
Werra				145.08	145.70	+0.62	6.20	6.20	
Wurtemburg State				1,044.70	1,025.48	—19.22	1.24	1.24	
Total	474.92	438.34	—36.58	32,072.60	32,618.20	+545.60	264.12	259.16	—4.96

Railways.	Metal track.								
	On longitudinals.			On cross-ties.			Other systems.		
	1890.	1891.	Increase (+) or decrease (—).	1890.	1891.	Increase (+) or decrease (—).	1890.	1891.	Increase (+) or decrease (—).
	Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*
Alsace-Lorraine	527.00	506.54	—20.26	329.22	368.28	+39.06	7.44	11.78	+4.34
Baden State	3.72	4.34	+0.62	807.24	892.80	+85.56			
Bavarian State	416.02	450.74	+34.72	199.02	262.26	+63.24	6.20	6.20	
Hesse-Louis	79.98	79.36	—0.62	343.48	350.30	+6.82			
Hessian State	0.62	0.62		3.10	3.10				
Lubeck and Buchen				45.26	47.74	+2.48			
Luxembourg	24.18	22.94	—1.24	40.68	41.92	+1.24			
Main-Neckar				53.94	57.04	+3.10			
Marienburg				102.92	103.54	+0.62			
Mecklenburg State				6.82	6.82				
North German									
Oldenburg State				6.82	11.78	+4.96			
Palatinate				102.92	136.40	+33.48			
Prussian State:									
Altona	8.68	9.92	+1.24	18.60	42.16	+23.56	4.34	4.34	
Berlin	646.66	653.48	+6.82	1.24	0.62	—0.62			
Breslau	6.82	6.82		193.44	182.90	—10.54			
Bromberg	202.12	197.78	—4.34	162.44	89.28	—73.16	13.64	13.64	
Cologne (left bank)	233.12	227.54	—5.58	1,379.50	1,519.62	+140.12	5.58	4.34	—1.24
Cologne (right bank)	210.18	205.84	—4.34	833.90	975.88	+141.98	6.20	5.58	—0.62
Elberfeld	31.00	27.28	—3.72	1,015.56	1,068.26	+52.70			
Erfurt	96.10	76.88	—19.22	335.42	383.16	+47.74			
Frankfort	682.62	683.86	+1.24	76.80	84.24	+7.44			
Hanover	342.24	329.22	—13.02	228.16	239.94	+11.78			
Magdeburg	16.12	15.50	—0.62	257.30	274.04	+16.74	3.10	2.48	—0.62
Saxony State				0.62	0.62		0.62	1.24	+0.62
Southeast Prussia				59.52	58.90	—0.62			
Werra									
Wurtemburg State	16.74	16.74		510.26	539.40	+29.14	12.40	12.40	
Total	3,543.92	3,515.40	—28.52	7,185.18	7,812.00	+626.82	59.52	62.00	+2.48

In the early part of 1893 the low prices of steel induced the State railway authorities to give out some large orders for ties. The Baden State railways contracted for the supply of 24,600 tons for 1893–1895.

The Prussian State railways also negotiated, offering $24.75 per metrical ton, but the makers asked $25.75. The exports in 1892 and 1893 are given in the accompanying table, and those sent to Venezuela were either ordered from or sent by way of the United States and therefore erroneously stated in the official figures twice over as exports to the United States and to Venezuela:

German exports of metal ties.

	1892.	1893.
	Tons.	*Tons.*
Great Britain	1,539	983
France	139	....
Holland	2,492	1,619
Belgium	1,856	334
Switzerland	3,734	12,819
Turkey	7,281	829
Cape Colony	569	....
Transvaal	1,046	2,150
Brazil	2,111	538
Chile	564	....
Venezuela	1,668	4,368
Mexico	1,804	1,899
United States	1,668	4,368
Total	26,471	29,907
Total, including fastenings, etc	37,000	39,000

In 1889 the U. S. consul at Dusseldorf reported that the appropriations by the state during the past year had been $2,250,000 for wooden ties, and $1,000,000 for metal ties, while the value of imported ties was estimated to amount to $450,000. The minister of railways was petitioned to make a more general use of metal ties in order to give increased work to the iron and steel industries, the situation of which was not good, and it was urged that the weight of metal ties, which then averaged 88.16 pounds, was too light, and should be increased to 132.24 pounds. The following figures of cost were presented at that time (the metal ties are described in my original report); they were both 8 feet 2½ inches long, and the Berg-and-Marche ties weighed 119½ pounds and the attachments 5.29 pounds:

	Metal. Berg-and-Marche Railway.	Metal. Rhenish Railway.	Wood. Oak.
Tie	$1.60	$1.56	$1.05
Rail attachments	.17	.18	....
Tie-plates	....	....	.10
Spikes	....	....	.12
Total	1.77	1.74	1.27
Deduct for old material	.68	.68	.12
Net cost	1.09	1.06	1.15

ALSACE-LORRAINE STATE RAILWAYS* (gauge, 4 feet 8½ inches).—In May, 1894, Mr. Frantz Heindl wrote me that his system of metal cross-tie (see Austria) will be laid this year on 6.2 miles of track.

BADEN STATE RAILWAYS* (gauge, 4 feet 8½ inches).—The experience of this railway, as given in the following official statement, represents the general experience and practice of German railways in regard to metal track. The use of metal ties is being increased rapidly, but the longitudinals are being abandoned. The percentage of track laid with metal ties has increased from 18.1 per cent in 1884 and 64.3 per cent in 1890 to 80.25 per cent in 1893. The following statement was furnished for the purpose of this report in April, 1894:

> The Baden State railways had in 1893 a length of 901¼ miles, of which 348¼ are double track and 553 miles single track. Of the main track, which aggregates 1,187 miles, and which is gradually being relaid with metal ties, there were 952¼ miles (or 80.25 per cent) with metal cross-ties, 2¼ miles (or 0.21 per cent) with metal longitudinals, and 232 miles (or 19.54 per cent) with wooden cross-ties. It is intended to substitute metal ties for the longitudinals, as experience with them has been unsatisfactory in respect to the maintenance of gauge and the draining of the track. At the same time the rails, which are too light for the cross-ties, will be replaced.
>
> The deterioration of iron ties results almost entirely from rusting, and has significance only in wet tunnels. Experiments with tar and paint have been made to prevent rusting, but so far no definite results have been arrived at. Crushing of the rail base into the metal of the tie has not been observed to any extent, and this effect in itself has not led to any renewals. No breakages of ties have been recorded, but longitudinal cracks or splits have been found at the turned-down ends of the ties, these being mainly confined to the older forms and being due to defective manufacture or to bad treatment in handling or tamping.
>
> The rattling noise when trains are passing over track with iron ties is disagreeable only until the ties have become firmly settled in the ballast. As soon as the ties have, after repeated tamping, reached a permanent position and bed, the noise is not essentially different from that on wooden ties. Weak rail joints are a much greater cause of noise than are the metal ties. Our rail fastenings are exclusively bolts, without nut locks, and only satisfactory experiences of their efficiency have been recorded, which is to be explained by the form of the clamps causing them to act as springs. These parts are specially watched by the trackmen, who pass over the track of our main lines at least three times a day.
>
> The cost of maintenance of the track with iron over wooden ties can not be stated separately for 1893; and even if stated would give but an imperfect idea of the cost of maintenance on the whole, as since 1891 we have been establishing on the main tracks, our Heidelberg, Basel and Mannheim, and Karlsruhe divisions, the heavier track shown on the accompanying drawings, as rapidly as possible so that on these divisions a speed of 56 miles per hour can be attained. In 1890, when 64.3 per cent of our main track was laid with metal ties, the cost for all track with iron and wooden ties was $377.42 per mile, of which $277.42 was for the purchase of rails, ties, track material, fastenings, and ballast, and $100 for labor. In 1884, when only 18.1 per cent of all main track was on iron ties, the total cost for maintenance was $422.58, of which $322.58 was for material and $100 for labor.

The heavy track referred to in the above statement is shown to be carried on ties of the modified "Berg-and-Mark" section (Pl. 12, original report). These ties are 7.38 feet long, 4.4 inches wide on top, 8.8 inches wide over the outer edges of the top slope, 9.68 inches wide over the bottom ribs, and 12 inches over the flared ends. The depth is 3 inches in the trough and 5.8 inches over the ends (measured from the higher end of rail seat to the bottom of the end, which projects below the trough section). The middle of the tie is horizontal for 3.82 feet, slopes upward at the rail seats for 1.12 feet, and then slopes down to the rounded end, which is curved to a radius of 4 inches. The rise of the rail seat is 0.68 inch. The top table is 0.44 inch thick and the sides 0.28 inch, and the bottom ribs project 0.44 inch beyond the sides of the tie. The bolt holes are 1.52 inches square, with rounded corners, 6.04 inches apart center to center, and are punched on the center line of the tie. The weight of the tie is 117.7 pounds.

The fastenings are bolted clamps, but differ somewhat from the original design shown on plate 13 of my original report, the eccentric gauge washer having the lower part smaller than the upper, so as to drop into the bolt-hole of the tie. The washer is 1.84 inches square on top and 1.48 inches below, the upper part being eccentric to the lower, so that by turning the washers to one or other position, the gauge may be varied. By the combinations of these changes on the four clamps of each tie, no less than 20 widenings of gauge of 0.40 inch each can be effected, giving a maximum gauge widening of 0.8 inch. Such minute variations, however, are an unnecessary refinement of little practical value, and involve a very objectionable complication if carried out in the track. Over the washer is placed a channel-shaped clamp, one side bearing on the rail and the other on the tie. This clamp is 2.8 by 2.96 inches, with a slotted hole 0.84 by 1.28 inches. The vertical bolts passing through the tie, washer, and clamp are 0.8 inch diameter and 3.2 inches long under the head, having a neck 0.84 inch square and a T-head 1.04 by 2.08 inches. The nut is hexagonal, with an inscribed circle of 1.56 inches, and is 1 inch thick. No nut lock is used, the surface of the channel-shaped clamp having a tendency to spring under the pressure of screwing up the nut, and thus putting a strain upon the nut. The bolt and nut weigh 1.21 pounds; gauge washer, 0.5 pound; clamp, 1.32 pounds, say 3 pounds in all, or 12 pounds for the four sets of fastenings on each tie.

The rails are of T-section, weighing 72 pounds per yard, laid with even suspended joints spliced by 28-inch angle bars and four bolts, the angle bars having lower webs below the rail through which are driven a transverse bearing plate and a taper key between the plate and rail base, thus holding the angle bars tightly down upon the rail base. There are 13 ties to a rail length of 29.52 feet, and 17 to a rail length of 39.36 feet. The spacing is 21.6 inches at the joints, then one of 24 inches, one of 26 inches, and one of 28 inches, the remainder being 30 inches center to center, except the three middle ties which are spaced 31.2 inches. The weight of track is 315 pounds per yard, exclusive of joint fastenings, while the metal track described in my former report weighed 267 pounds per yard.

Barmen Mountain Railway (gauge, 3 feet 3⅜ inches).—This is a steep grade electric street railway, 1 mile long, operated on the rack system, having the Marsh (or Riggenbach) ladder rack laid with its surface flush with the pavement. The line is double track throughout, with grades of 18.52 and 13.9 per cent, and the sharpest curve is 500 feet radius. The track is of grooved girder rails in the streets, and T-rails elsewhere, bolted to steel ties of trough section placed 40 inches apart, and the channel bars forming the sides of the rack rail are also bolted to the ties. Outside the paved streets the track is ballasted with gravel. The cars are of street-railway pattern, but with four compartments, the end compartments entered from the platforms, and the middle ones having side doors. There are two spur wheels, each driven by a 30-horse-power motor, the current being taken by sliding contact frames from overhead wires. This type of track construction (without the rack) is quite common in Germany and other European countries.

BAVARIAN STATE RAILWAYS* (gauge, 4 feet 8½ inches).—In my original report it was stated that the Heindl system of steel cross-ties (*see* Austria) had been adopted as standard for metal ties on main tracks (and used also on secondary lines), and that up to the end of 1887 they had been laid for a length of 85.61 miles. Mr. Heindl sends me a statement showing that 410.17 miles had been laid up to the end of 1893 (as detailed in the table given later on). The following is an abstract of a statement made in 1892 in regard to these ties:

> The security is excellent, there is no widening of gauge, and the line and surface are well maintained, the only depression being at the rail joints, and that but slight. The cost for maintenance during the first three years is greater than for wooden ties, but after that time the metal track needs very little regulation if laid on stone ballast. The rail section and type of fastenings are satisfactory. The safety at and against rail breakages is the same as on wooden ties. Lateral motion occurs only when first laid in sand ballast. The life of the ties can not be estimated, as after seven years' service no wear could be observed on the ties or fastenings.

BREMERHAVEN RAILWAYS.—At the new port of Bremer, on the Weser River, there are about 28 miles of railway tracks. Part of the track is laid with the Haarmann compound T-rail, 8 inches high and 12 inches wide over the base, having generally a guard rail resting on the rail base and bolted to the track rail, thus leaving an open flangeway of 1⅞ inches. Spacing pieces are bolted between the track and guard rails, and the same bolts hold the ends of the flat tie bars. In some cases there is a track of similar but lighter construction for a narrow-gauge track between the standard-gauge track rails, making a very complicated arrangement. The rest of the line has ordinary T or flange rails bolted to steel cross-ties, with the Haarmann hooked tie plate between rail and tie. (*See* Haarmann metal track and Pl. 2.)

HESSE LOUIS RAILWAY* (gauge, 4 feet 8½ inches).—The statement furnished for my original report recorded the unsatisfactory experience with the Hilf system of longitudinals, and continued experience shows the same results, as will be seen from the following official statement furnished in June, 1894. The wear of the longitudinals is probably due to the fact that the tendency to wave motion is very much greater with the 52-pound rails on longitudinals than with the 70-pound rails on the cross-ties, while wave motion is much better provided for on the latter than on the former track:

> The base of the rail wears more or less into the surface of the metal bearings. This is especially the case with longitudinals, as with cross-ties the rails are transverse to the direction of the rolling of the fiber of the tie and the wear is thus somewhat less. When metal ties are properly embedded in the ballast, there is hardly any perceptible difference in noise of trains running over track on wooden or metal ties, although as a rule there is a slightly smoother passage over the former. The

rail fastenings have stood the wear and tear very well. We have so far no reliable records at hand as to the cost of maintenance of track laid with metal ties, but so far as we know the cost of use does not differ materially from that for track on wooden ties.

PRUSSIAN STATE RAILWAYS (gauge, 4 feet 8½ inches).—Mr. Franz Heindl informed me in May, 1894, that 12½ miles of track will be laid with his system of metal cross-ties (*see* "Austria") during this year.

Cologne Division, left bank of the Rhine * (gauge, 4 feet 8½ inches).—A very complete statement from this division was given in my former report, and in May, 1894, the following official statement was furnished:

> On our division there are 1,751½ miles of track on metal cross-ties out of a length of 2,552½ miles. In regard to wear and tear, rust or fractures of ties, we have, so far, no sufficient observations for judging of the durability of the iron ties. When trains run over a track with iron ties having a weight of about 110 pounds, no greater noise can be distinguished than when the track is laid on wooden ties. The fastenings hold well and do not need frequent inspection. The cost of maintenance depends so much upon the manner of first construction and on the traffic that it is not possible to give average figures for the same.

The fastenings referred to are bolted clamps on the Ruppell system, shown on Plate No. 13 of the original report. In 1888 this division had 1,682 miles of track, with 943 miles on metal cross-ties, 241½ miles on metal longitudinals, and the balance on wooden cross-ties.

Elberfeld Division * (gauge, 4 feet 8½ inches).—From this division a detailed statement was received in 1888 and published in full in the original report, showing that in 1887 it had 790 miles of track on wooden cross-ties, 762 miles on metal cross-ties, and 93 miles on metal longitudinals. In May, 1894, the following official statement was furnished for the purpose of this present report:

> On the main tracks of our division there are 201½ miles of track on wooden ties, 915 miles on metal ties, and 15 miles on metal longitudinals. The latter system may be considered as having been abandoned, and what remains will be replaced by metal cross-ties. In regard to securing the correct gauge, and in connection therewith the safety of operation, our opinion is that metal ties are preferable to wooden ties. Ruptures and cracks in metal ties have, it is true, been observed repeatedly, but only at the ties of lighter weight and section, which could not withstand the greater loads and increased traffic and greater velocity. These ties have been gradually removed from the main tracks, and the new ties of heavier section are 8.86 feet long and weigh 128.26 pounds. There are generally 11, and exceptionally 12, ties to a rail length of 29.52 feet. No fractures have occurred in these ties. Deterioration of metal ties by rust has only been observed in long and damp tunnels, and in such tunnels, therefore, wooden ties are still principally used. The noise and rattling of trains running over metal ties is greater than over wooden ties, but considering the other advantages of metal ties this circumstance does not count for much.
>
> The method of fastening used on our road is that of gibs and cotters, or keys, on the Vautherin system (*see* Pl. 13 of original report); a loosening of the parts can possibly occur, and hence a certain amount of care is advisable. During recent years the fastenings adopted on new lines and in renewals are on the Haarmann system (Pl. 2) with hooked tie-plates and bolted clamps. This arrangement proves to be very satisfactory, and it is not necessary to inspect the fastenings frequently.
>
> As to the cost of materials and labor in the maintenance of track on iron and wooden ties, we are not prepared to give exact figures. The cost depends especially upon the roadbed, the weight and speed of trains, and the amount of traffic. A

comparison between the cost of maintenance of track on iron or wooden ties as actually observed on our road would not give a correct answer to the question, because wooden ties are exclusively used only on side roads with little traffic, while the main track, provided with metal ties, is in part subjected to an extraordinarily large traffic. According to our experience, metal track requires less labor for maintenance than a track on wooden ties. In the first year, it is true, the metal ties require more tamping, but as soon as the ballast has settled well under the ties the cost of maintenance is smaller than for wooden ties. Change of gauge can only occur in consequence of the wear of the parts, which is very slow, while with wooden ties much time and expensive labor are necessary to regulate the gauge. One other circumstance comes into consideration in regard to cost of maintenance, namely, that the metal ties have a height of only 3 inches, while the wooden ties are 6.4 inches high. In tamping old tracks the ballast must be removed sufficiently to allow the lower edge of the tie to be reached by the tamping tool, hence the time necessary for removing the ballast and filling and dressing off again is only about half as much for metal ties as it is for wooden ties.

Hanover Division * (gauge, 4 feet 8½ inches).—The Haarmann compound self-bearing rail (*see* Pl. 2) was laid in 1885 between Minden and Hanover, on the Cologne and Berlin line, and up to 1894 the cost for maintenance had been 50 marks per kilometer per year, or $16 per mile per year, with no expense for new ballast or other material.

HAARMANN METAL TRACK.

A number of designs of metal track and appliances therefor have been invented and introduced by Mr. Haarmann, director-general of the Georgs-Marien Bergwerks- und Huetten-Verein, at Osnabruck, and I am indebted to his assistant engineer, Dr. A. Vietor, for particulars of these devices, which are commonly known by the inventor's name. Reference may be made here to Mr. Haarmann's valuable and exhaustive book on Railway Track, which is noted more particularly in the chapter on Historical Development, page 209.

(1) *Haarmann's tie-plates.*—This form of hooked tie-plate for metal ties, fastened by lugs and vertical bolts (*see* Pl. 32), has been in use since 1882, and found to be a very simple and successful device. The plate gives to the rail the inward inclination generally required in European railway construction. As there is no bolt on the outer side of the plate, which has one lug below to engage with a hole in the tie and another lug on top to hold the rail flange, the ballast can, if desired, be filled into the rail head on the outer side of the track. As on German railways it is the practice to widen the gauge on curves of over 975 feet radius, four different sizes of plates and clamps allow of eight variations in gauge of 3 millimeters, or about one-eighth inch, from 4 feet 8½ inches to nearly 4 feet 9¼ inches. The arrangement is somewhat complicated in track-laying, and the combinations are shown in the table, the tie-plates and clamps being numbered 0, 1, 3, 4.

Gauge.			Widening of gauge.		First rail.		Second rail.	
					Tie-plate No.	Clamp No.	Tie-plate No.	Clamp No.
Ft.	*in.*	*Mm.*	*Inch.*	*Mm.*				
4	8½	1,435	0	0	4	0	1	3
4	8⅝	1,438	⅛	3	3	1	1	3
4	8¾	1,441	¼	6	4	0	3	1
4	8⅞	1,444	⅜	9	4	0	4	0
4	9	1,447	½	12	3	1	4	0
4	9⅛	1,450	⅝	15	1	3	3	1
4	9¼	1,453	¾	18	1	3	4	0
4	9½	1,456	⅞	21	0	4	4	0

It is also possible to make the gauge tight or narrow by generally using plates Nos. 4 and 3 instead of two No. 4 plates for the standard gauge. About 12,000,000 of these plates have been sold within twelve years, for 3,150.7 miles of track up to April 1, 1894, as follows:

	Miles.		Miles.
1882	4.35	1890	443
1883	5.65	1891	639.50
1884	45.20	1892	127
1885	56.50	1893	501.50
1886	77.50	1894 (to April)	365
1887	213.50		
1888	334	Total	3,150.70
1889	338		

(2) *Haarmann's longitudinals* (Pl. 12 of original report).—Longitudinal bearings or sleepers have been in use on German railways for many years, but the experiments with them did not give such results as to encourage their continuance. The principal defect of all the systems with separate sleepers and rails (the rail and sleeper not forming one solid girder or stringer) was the wear between rail and sleeper, not only at the joint, but all along the track. This was found to be due to the insufficient strength and resistance of the system, on account of which the deflection or wave motion under trains was very considerable, entailing very high expenses for maintaining the ballast and track in good condition. Another defect was the weakness of the joints, which could not be spliced so well as to give them at least the same amount of bearing capacity, strength, and stiffness as the rails and sleepers had between the joints. The same weakness in track with cross-ties can be remedied by closer spacing of the joint ties, but this, of course, can not be done with longitudinals, and the use of metal cross-ties under the joints of longitudinals has not been found satisfactory. Mr. Vietor says: "During the last few years we did not turn out any longitudinal sleepers, and the system as a whole may be considered as having totally failed."

(3) *Haarmann's compound rail* (Pl. 12 of original report).—Experience with the metal ties and longitudinals led to the design of the compound self-bearing rails, first introduced on the steel works company's lines near Osnabruck. The general form was shown on Plate 12 of the original report, and the present form, with scarfed joint, is shown on Plate 32, appended hereto. The rails are scarfed or halved for several inches from the end, and secured by eight bolts, six of which pass through both rails. The rail forms a high, strong, and stiff stringer, whose moment of inertia and resistance are several times as great as those of separate rails and stringers of equal weight (each of which is too weak in itself). The deflections are thus very greatly reduced, and the great difference in this respect between the self-bearing rail and the ordinary T-rail on cross-ties during the passage of trains was shown by diagrams forming part of Mr. Haarmann's wonderful track exhibit at the World's Columbian Exposition at Chicago in 1893. In some cases the deflections measured on tracks with longitudinal sleepers were even greater than those on tracks with cross-ties. Dr. Vietor writes as follows:

"In general these diagrams prove the principle that the stronger the rail the smaller are the maintenance expenses, including in the rail the gain of strength by being laid on sleepers or not. It is true that a rail laid upon sleepers need not be of the same strength and weight as a self-bearing rail, but I do not think that the equality of strength and resistance of a heavy, high, and stiff self-bearing rail could ever be reached by a smaller rail laid upon wooden or metal cross-ties, nor that the amount of strength and resistance of such a stiff rail could ever be given to a complicated track consisting of rails and sleepers, provided that the construction does not exceed economical limits. Hence the very important fact that the maintenance expenses on track with the Haarmann compound self-bearing rails proved to be so exceedingly low. But there is another point which must be considered as adding considerably to this fact, and that is the construction of the joints. The two half beams of angle section forming the rail are made to overlap or break joints, and each half beam is spliced not only by special angle bars much heavier than those used with rails on cross-ties or longitudinal sleepers, but also by the other half beam or half rail. Thus each half rail has practically three strong splice bars, while in the usual system of track with rails on cross-ties each joint has only two splice bars (generally smaller). Besides this, each half beam represents a bridge-like guide to carry the wheels over the joint of the twin beam."

It will be understood that the novel and radically different type of this track from the ordinary track prevented its being generally and rapidly introduced, and many prejudices and arguments had to be met and overcome by practical results. This however, is now claimed to have been done, as a long service on different lines is said to show an extraordinarily low amount of maintenance work. A section of this track was laid in 1885 between Minden and Hanover on the Cologne and Berlin line of the Hanover Division of the Prussian State railways, and a piece of this was taken out in the early part of 1893 to be sent to Chicago. The railway administration had then found an average of 50 marks per kilometer per year, or, say, $20 per mile per year, for maintenance expenses, with no expense at all for new ballast or other material. Dr. Vietor says: "I do not know any main line in the world where such results would have been obtained. It shows the way to save money in railroading." The company's mills are now at work on orders for 1894, and the mileage of this track already laid is as follows:

	Miles.		Miles.
Before 1885	2.5	1890	1.0
1885	7.3	1891	5.5
1886	0.1	1892	1.3
1887	16.2	1893	30.0
1888	4.0		
1889	14.7	Total	82.6

A somewhat modified form of this track, designed by Mr. Vietor, has a single rail of section similar to the compound rail, rolled with the web nearer one side of the rail head instead of being directly under its center, so that by cutting away the side of the head a scarf joint can be made with both rail webs side by side, spliced by angle bars and bolted through with six bolts, the four middle bolts passing through both rails and both splice bars, and the two end bolts passing through one rail and both splice bars. The scarf is about 8 inches long. He has also designed a T-rail of general dimensions (to be laid on metal or wooden cross-ties) in which the same arrangement of head and web is used, so as to permit of the use of the scarf joint, which it is hoped will be given a trial in this country, where the rail joints give so much trouble.

AUSTRIA AND HUNGARY.

GENERAL REMARKS.—In Austria the Hohenegger system of metal longitudinals and the Heindl system of metal cross-ties are both extensively used, and favorable results are reported in each case. The former is used on one road only, while the latter is used on several roads, and its use is being extended. The Heindl system, although favorably considered in Europe, is open to the objection of complication and number of parts in the fastenings, while, on the other hand, to these fastenings are mainly attributed the low cost of maintenance on one road using them.

Summary of metal track in Austria, Hungary, and Bosnia.

	Longitudinals.	Cross-ties.	Total.
	Miles.	*Miles.*	*Miles.*
Aussig and Teplitz Railway		0.62	0.62
Austrian State railways		150.00	150.00
Emperor Ferdinand Northern Railway		1.24	1.24
Galician (Carl Ludwig Railway)*		.62	.62
Northwestern Railway	56.00		56.00
Southern Railway		.34	.34
Total for Austria, 1894	56.00	152.82	208.82
Hungarian State railways *		1.50	1.50
Hertzing and Pertchtoldsdorf Tramway *	6.43		6.43
Bosnia-Herzegovina State Railway		11.72	11.72
Total for 1894	62.43	166.04	228.47
Total for 1890	66.56	56.37	122.93

* Figures from original report.

AUSSIG AND TEPLITZ RAILWAY* (gauge, 4 feet 8½ inches).—The following return was made in 1892 in regard to the Heindl steel ties, which were of section A, for main tracks, laid for 0.62 mile in 1883:

In 1883 there were 1,106 ties laid, and they have fulfilled all requirements, keeping perfect line, surface, and gauge. The cost of maintenance is 110 florins per kilometer per year, as against 230 florins for wooden ties, and no new material has been required. The ballast is of broken stone and gravel and behaves well. The tie is 7.87 feet long and weighs 158.4 pounds. The ends are closed. The rails weigh 70 pounds per yard, and the track 328 pounds per yard. The ties offer greater resistance to lateral motion than the wooden ties. The life will probably be of long duration.

AUSTRIAN STATE RAILWAYS.* (gauge, 4 feet 8½ inches).—As stated in my former report, extensive experiments have been made with the Heindl type of steel cross-tie, of which 38 miles had been laid in the main track up to the end of 1893 (see notice of the Heindl tie farther on). Of this total 10.75 miles are on the standard gauge Eisenerz-Vordenberg rack railway, laid with the Abt rack-rail system. Up to the present time about 3,000 switches have been laid with metal ties, representing a length of 112 miles. These ties are also laid through the Arlberg tunnel. The following is an abstract of a statement issued in 1892 relative to the early sections of track laid in 1883:

The traffic is heavy, with a maximum speed of 31 miles per hour. The safety and condition of the track are perfect. The cost for maintenance is higher than with wooden ties, but less material is required. No wear has been observed, no ties have been renewed, and the shape of ties and fastenings is satisfactory. Good ballast is an essential condition for good track, and the ties must be well tamped. A few of the bolts broke.

The ties laid in 1886 on the Severic-Knin division of the Knin-Spalato line for 13 miles weighed 123 pounds, being type "C," for lighter lines. They are 5.2 inches wide on top and 9.2 inches over the lower vertical parts of the sides; the total height is 3.2 inches, of which the lower 1.8 inches are vertical. The ends are bent down vertically, the depth over end being 4 inches. The top is 0.34 inch thick, the inclined sides 0.32 inch, and the vertical part tapering from 0.28 inch downward to 0.16 inch. This track is well adapted to the conditions, but the traffic is light.

The railway administration placed large orders in 1892 with Austrian rail mills for the Heindl steel ties, and in 1893 the records for the previous eight years showed a decided saving in cost of maintenance for track laid with these ties as compared with track laid with oak ties treated by the chloride of zinc process. The entire saving for the eight years was 13.8 per cent. It was stated that the attachments of the rails to the ties required no tightening, and that there were no signs of wear, no breakages of rails, and no creeping of the rails.

EMPEROR FERDINAND'S NORTHERN RAILWAY* (gauge, 4 feet 8½ inches).—As stated in my former report, the Heindl steel cross-ties were laid in August, 1883, for a length of 1.24 miles. Up to the end of October, 1891, this track had carried 25,668 passenger and express trains, 50,323 freight trains, and 2,325 mixed trains, or 78,516 trains in all, with an average load of 527 tons, and a maximum express speed of 50 miles per hour. During these eight years, and with a traffic of 41,370,000 tons, the track behaved excellently. No accidents occurred. The maintenance required less labor than for wooden ties, and the cost of maintenance during the first seven years was 6.2 per cent less than for wooden ties, and 26 per cent less for the first ten years. The traffic up to the end of 1893 included 18,300 express trains, 21,682 passenger and mixed trains, and 66,895 freight and military trains; an aggregate of 103,877 trains, representing a traffic of 55,470,000 tons.

The ties are of mild steel, 7.87 feet long, weighing 157.6 pounds, and carry Bessemer steel rails weighing 70½ pounds per yard. They are spaced about 3 feet apart, but closer at the suspended joints. The fastenings of the rails to the ties are excellent, do not show any loosening or wear, and no lateral motion is permitted. No rail breakages occurred in eight years, and no ties had to be renewed. The life of the ties could not be estimated. The punched holes were found perfect in shape and dimensions, with edges sharp and unworn, and neither base plates nor clamps showed wear. The bolts also showed no wear, but 261 (or 0.38 per cent) had to be renewed on account of breakage; but this was due to bad handling of the tools and was not a defect in the system. The cost of maintenance per mile for 1.24 miles of track with metal ties, and 3.50 miles with oak ties treated with chloride of zinc, is given in a published table, of which the following is an abstract, and Mr. Heindl has furnished me the figures for the last three years:

	Steel ties.				Wooden ties.			
	Labor.	Material.	Ballast.	Total.	Labor.	Material.	Ballast.	Total.
1884	$257.31	$1.50	....	$258.81	$214.90	$2.58	....	$217.48
1885	255.89	5.83	....	261.72	265.74	8.86	....	274.60
1886	171.39	5.84	$27.73	204.96	196.70	8.91	$12.69	218.30
1887	126.73	2.56	....	129.29	152.59	6.18	9.98	168.75
1888	172.37	6.93	....	179.30	194.24	10.27	....	204.51
1889	152.57	17.79	....	170.36	143.23	24.36	....	167.59
1890	96.74	14.05	....	110.79	110.27	40.49	....	150.76
Total, 7 years	1,233.00	54.50	27.73	1,315.23	1,277.67	101.65	22.67	1,401.99
1891	73.42	4.60	....	78.02	108.70	104.92	....	213.62
1892	86.53	10.63	....	97.16	112.83	156.42	....	269.25
1893	86.34	11.85	....	98.19	86.90	177.03	....	263.93
Average, 1884-1890	176.14	7.78	3.95	187.87	182.52	14.52	3.24	200.28
Average, 1884-1893	147.93	8.15	2.77	158.85	158.61	54.16	2.27	215.04

The assistant director of permanent way and works in 1892 prepared a statement in regard to the cost of maintenance of the abovementioned track, in answer to a statement by Mr. Janssen, of the Belgian State railways, showing unfavorable results as to the cost with the metal track in use on the latter roads. During the nine years trial, under heavy traffic, the metal track remained intact, while the track on wooden ties presented signs of wear corresponding to the traffic and age. Both systems of track had the same rails and rail joints and carried the same traffic. He attributed the perfect security of the rail fastening to the use of a tie-plate prevented from motion on the tie, thus avoiding any direct thrust of the rail flange upon the outer fastenings or upon the tie itself, while the plate also serves to distribute the effects of shocks on the rail head. The rapid deterioration of ballast noted on the Belgian State railways, requiring the laying of enormous quantities of broken stone, he attributed to a defective system of fastenings on the Post and Braet ties and the consequent hammering of the ties, to the absence of tie-plates, and to the use of too hard a steel. He prepared also the following comparative statement of Mr. Janssen's figures of the average per mile per year for cost of maintenance for five years on the Belgian State railways and the figures per year for an average of nine years on the Emperor Ferdinand Northern Railway:

	Labor.	Material.	Ballast.	Total.
Belgian State railways:				
Oak ties	$26.66	$1.93	....	$28.59
Post steel ties	261.37	12.86	$282.10	556.33
Braet steel ties	205.32	15.54	315.80	536.66
Emperor Ferdinand Northern Railway:				
Oak ties	166.58	40.51	2.51	209.60
Heindl steel ties	154.77	7.75	3.07	165.59

In 1891 the cost of maintenance per mile was $213.62 for the track on wooden ties and $78.02 for that on steel ties.

A general summary of these details of cost of maintenance per mile are as follows, including labor, track material, and ballast:

Year.	Track on metal ties.	Track on wooden ties.	Year.	Track on metal ties.	Track on wooden ties.
1884	$215.26	$178.52	1890	$92.35	$109.60
1885	218.08	228.80	1891	65.02	177.98
1886	170.73	181.89			
1887	107.72	139.81	Total	1,160.49	1,326.05
1888	149.41	170.40	Average	145.06	165.83
1889	141.95	139.65			

This shows an economy in cost of maintenance of 13.8 per cent in favor of the metal track. The great increase in the cost for 1891 on the track with wooden ties is due to the fact that the necessity for renewal began to impose itself. It is evident that this renewal will in future constantly increase the cost of maintenance.

NORTHWESTERN RAILWAY* (gauge, 4 feet 8½ inches).—The Hohenegger system of metal longitudinals, as used upon 59½ miles of this railway, was fully described in my original report (p. 158) and this system of track was advocated by Mr. Thomas C. Clarke, M. Am. Soc. C. E., in a paper read before the American Society of Civil Engineers in 1891. The paper was accompanied by a letter from Mr. Hohenegger, which I give below, substantially in full. Some extracts from the discussion on the subject when presented before the society, and some further remarks on the question of the relative merits of longitudinals and cross-ties, are given in Part II of this report.

I have used in my system of superstructure with longitudinal bearers that is discussed by you both the combined joint and the broken joint. In the latter the joints of tie and rail do not coincide. The combined joint, in which rail and longitudinal bearer butt against each other on the saddle-shaped splice, facilitates the laying of the superstructure somewhat, and gives generally good results, because the carrying capacity of rail angle bars and of tie splice equals about that of rail and of longitudinal. The broken joint, however, seems, in the length of time, to offer more resistance against the depression of the joints. I have tried both systems from the beginning, in order to gather experience and to reënforce, if necessary, those parts of the joints which should prove too weak. Obvious weaknesses in this regard have not been noticed up to the present time, but I would now give a larger bearing surface to the tie saddles.

The fastening of the rails on the longitudinal bearers by means of wedge-shaped clamps which bear against wedge-shaped ribs of the longitudinal bearers proves eminently satisfactory, with the only alteration that we used two-sided unsymmetrically formed clamps instead of the one-sided ones, to facilitate the obtaining of the correct gauge where the cross-ties are not well punched or where they are bent, as in curves. The wedge-shaped form of the clamps has done away entirely with the very undesirable rusting together of the bolts with the bearers. The exchanging of worn-out or injured rails is effected very easily without any disturbance whatsoever of the position and of the fastenings of the longitudinal bearer.

Within the fourteen years of the existence of this superstructure with longitudinal bearers two cases only of breakage of rails have occurred, and in these several trains passed without derailment over the remnants of the rails that had been broken in many pieces. In both cases blow holes caused the heads of the Bessemer steel rails to be shattered in many small pieces, so that the wheels ran without being derailed, partly on the rail web, partly on the longitudinal bearers, though one of the broken pieces belonged to the outer rail of a rather sharp curve.

I have never introduced gauge rods proper, as they are used in the superstructure with longitudinal bearers of the German railways, but have been satisfied with one transverse angle iron for each 9.84 feet (3 meters) of bearers, fastened to the lower side of the bearers with short pieces on the saddles. This transverse connection has perfectly sufficed to maintain the gauge; if it should not prove sufficient more cross connections would be put in place without great expense, but they have not been necessary so far.

The longitudinal bearer, transverse angle tie, and tie saddles are easily tamped with gravel when the superstructure is newly laid. In later years, after the box-shaped volume of ballast underneath of the longitudinal ties has consolidated into a mass like concrete, the longitudinal bearers must be lifted off it, and this ballast has to be replenished by a layer of fine ballast. However, this work becomes necessary only very seldom, because the superstructure with longitudinal bearers retains its position much better than if laid with transverse ties, which each give way separately.

The raising of the superstructure when depressed is more difficult with iron transverse ties than with longitudinal bearers, for the reason that it is not possible to raise a single transverse tie without unscrewing a pair of rails, whereas with longitudinal bearers rail and bearer can be lifted together, necessitating only the loosening of the rail angle bars.

The ┬-shaped longitudinal, as tried in 1873 by the Rechts-Rheinische Railway (Prussian State Railway, Cologne Division, right bank of the Rhine), has not proved a success, because the vertical web of the ┬ tears asunder the box-shaped mass of compact ballast instead of holding it together and of gradually rendering it a unit. All longitudinal bearers and transverse ties similarly shaped have been discarded for some time as nonpractical. In order to lay the curves of the track the longitudinals have to be bent in the ironworks according to the requirements of the curve. The supervising engineer must have an accurate table that shows how the segments follow each other, and he must lay the longitudinals consecutively and in accordance with it. The laying is done very rapidly if this rule be observed. Up to 984 feet (300 meters) of track are put down per day on track where frequent trains are running. That is twice as much track as could be renewed with transverse ties. The superelevation of the outer rail does not offer any known difficulties. The connection with cross-overs and switches is not more difficult than in track with transverse ties, if rail angle bars of equal section are used and if the cross-overs are put down on transverse ties. We do not have cross-overs on longitudinal bearers. (The switch rails, however, are on the longitudinals.—E. E. R. T.)

The rails on longitudinal bearers are essentially lighter than those on transverse ties. They weigh only 54.32 pounds per yard (27 kilos per meter), against 66.4 pounds per yard (33 kilos per meter). Transverse fractures of rails have not yet occurred, those two cases excepted where the rails were destroyed through blowholes of the ingots. The rails are, as a matter of course, made of harder steel, while the longitudinal bearers are manufactured from soft Gilchrist-Thomas metal.

Up to date about 55.89 miles (90 kilometers) of track with longitudinal ties have been laid and have given satisfaction in every respect. The quicker extension of this system is retarded only by the high prices of the ironworks. Difficulties as to the drainage of this superstructure have not appeared; coarse, water-transmittent sand must be called the most appropriate material for ballasting. The superstructure with longitudinal bearers has especially given good service with sliding substructure. Our superstructure with wooden cross-ties has been considerably strengthened and has been made steadier by the introduction of the large tie-plates of my system. (*See* Pl. 2.)

SOUTHERN RAILWAY (gauge, 4 feet 8½ inches).—On the length of 0.55 mile between Leoben and the Seegraben collieries the Heindl steel ties were laid in 1884 for 0.34 mile on a grade of 3.33 per cent. According to a statement issued in 1892 the ties are of type "A" for main lines, 7.87 feet long, 6 inches and 10.4 inches wide on top and bottom, and 4 inches deep, weighing 154 pounds each. The rails are 24.6 feet long, weighing 70 pounds per yard. The track is completely safe, and there has been no loosening of bolts or widening of gauge. At first the track shifted somewhat, owing to the settling of the embankments, but now it is stable, and there is neither lateral motion of track nor creeping of the rails. The labor of maintenance is much less than for the wooden ties in the adjacent track under the same conditions of grade, etc., but no records of the actual cost have been kept. No rails, ties, or fastenings have been renewed. The total daily traffic is about 1,000 tons, or a total of 2,700,000 tons up to the time of the above statement. The ballast is of broken stone, which is preferable to river gravel, as it gives better drainage and adapts itself better to the slope of the interior of the tie. The weight and shape of the ties have proved satisfactory, and no wear is observable. The speed of trains is only 7.4 miles per hour, owing to the heavy grade. In 1852 the administration invited tenders for 35,000 metal ties.

TIES.

*Heindl tie** (*see* Pl. No. 2).—The steel cross-tie with bolted clamp fastenings, designed by Mr. Franz Heindl, chief inspector of the Austrian State railways, has been described in my former report (pp. 157, 163, and Pl. 14), and further particulars will be found under the headings of the several railways upon which they are used, a list of which (completed by Mr. Heindl to the end of 1893 for the purpose of this report) is given below. It has already been pointed out that the ties are very heavy, heavier in fact than seems neccessary, while the separation of each rail clamp into two pieces appears to be objectionable. There are five principal sizes of these ties, A and B for main lines, C and D for branch and less important lines, and E for narrow-gauge, secondary, and local railways. The general particulars of these are as follows:

		A.	B.	C.	D.	E.
Weight	pounds	158.4	138.6	116.6	112.2	68.2
Length	feet	7.57	8.20	7.57	7.57	5.25
Width on top	inches	6	5.20	5.20	4.80	8.80
Width over vertical sides	do	10.40	9.60	9.20	8.80	8.40
Height	do	4.00	3.60	3.20	3.20	2.80
Of vertical sides	do	2.40	2	1.80	1.80	1.60
Over end	do	5.20	4.80	4	4	3.60
Thickness—						
Of top table	do	.40	.36	.34	.34	.32
Of inclined sides	do	.32	.32	.32	.30	.28
Of vertical sides	do	.28 .16	.28 .16	.28 .16	.24 .16	.20 .16
Area of cross section,	square centimeter	36.70	31.04	27.36	26.46	23.30
Height from bottom to center of gravity	inches	2.82	2.50	2.25	2.22	1.98

The Heindl system is complicated, as has already been noted. For a 20-foot rail the following material is required: Eight ties, 4 splice bars, 8 bolts for splice bars, 16 tie-plates, 32 wedges, 32 fastening bolts, 16 braces. The first cost per tie, with accessories, is $3.82. The following table gives a list of the several railways upon which this system has been used:

Track laid with Heindl steel ties.

Year.	No.	Railway.	Location.	Length.	Length per year.	Maximum grade.	Minimum curve radius.	Type of tie.
				Miles.	*Miles.*	*Per ct.*	*Feet.*	
1883	1	Aussig-Teplitz	Ullersdorf-Dux	0.62	....	0.86	1,554	A
1883	2	Bavarian State	Regensburg division	.17	....	....	....	A
1883	3	Emp. Ferd. Northern	Angern-Durnkrut	1.24	....	.04	4,356	A
1883	4	Austrian State	Breitenschutzung-Schwanenstadt.	.62	....	.37	1,870	A
1883	5	......do	Kosten-Dux	.62	....	1.30	931	A
1883	6	......do	Grybow-Ptaszkowa	.06	3.33	1.80	984	A
1884	7	......do	Klaia-Bochnia	.62	....	.06	3,109	A
1884	8	......do	Arlberg tunnel, track No. 1.	6.63	....	1.50	984	A
1884	9	Southern (Austria)	Leoben-Seegraben	.34	7.59	3.33	492	A
1885	10	Bavarian State	Bamberg division	23.25	....	2.50	984	B
1885	11	Austrian State	Arlberg tunnel, track No. 2.	6.63	29.88	1.50	984	A
1886	12	Bavarian State	Munich, Rosenheim, and Wurzburg.	12.90	....	....	....	B
1886	13	Austrian State	Siverec-Knin	13.02	25.92	2	984	C
1887	14	Bavarian State	Munich and Rosenheim	14.77	14.77	....	....	B

Track laid with Heindl steel ties—Continued.

Year.	No.	Railway.	Location.	Length.	Length per year.	Maximum grade.	Minimum curve radius.	Type of tie.
				Miles.	*Miles.*	*Per ct.*	*Feet.*	
1888	15	......do	Bamberg, Ingolstadt	53.55	53.55			BD
1889	16	......do	Munich, Nuremberg, Regensberg.	24.04	24.04			B
1890	17	......do	Rosenheim and Würzburg.	35.11				B
1890	18	Bosnia-Herzeg. State	Konjica-Sarajevo	11.72	46.83	6	328	E
1891	19	Bavarian State	Same as 15, 16, 17	62				B
1891	20	Austrian State	Eisenerz-Vordernberg	10.54	72.54	7.10	590	C
1892	21	Bavarian State		106.05	106.05			
1893	22	......do		78.32	78.32			
		Total, to end of 1893, Germany (Bavaria).		409.82				
		Total, to end of 1893, Austria.		52.70				
		Total track		462.82				
		Total switches (Austrian State railways).		111.60				
		Grand total, end of 1893.		574.42				

BOSNIA.

Bosnia-Herzegovina State Railways (gauge, 2 feet 6½ inches).—On the line from Konjica to Sarajevo, a length of 11.72 miles was laid with the Heindl steel cross-ties in 1890. The maximum grade is 6 per per cent, the line being operated on the Abt rack-rail system. It is the mountain division of the railway from Ostrozac to Sarajevo, crossing the Ivan Mountains.

SWITZERLAND.

General Remarks.—The experience here has been about the same as in Germany, being so satisfactory that the use of metal ties has been considerably extended. The Gotthard Railway, for instance, has adopted them for switches as well as ordinary track. Metal ties are used also on a number of steep-grade rack railways, built for tourist travel. Statistics published in 1894 give the following percentages of metal and wooden ties on the five principal railways:

Railway.	Metal ties.	Wooden ties.	Railway.	Metal ties.	Wooden ties.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Swiss Central	60.1	37.9	United Swiss	17.9	82.1
Gotthard	57.7	42.3			
Northeastern	39.8	62.2	Average	41	59
Jura-Simplon	33.1	66.9			

The following summary of metal-track mileage is almost certainly very far below the existing mileage at the present time, and, judging from the above table of percentages and from the probable omissions, it appears fair to assume that the actual total is probably at least 500 miles instead of 449 miles. In the former report the actual total was given as 397 miles, as against a total of 304 miles compiled from returns. The numerous rack railways for mountain-climbing tourist traffic account partly for this.

On the five principal railways of Switzerland the percentage of track laid with steel ties is as follows: Gotthard Railway, 57.7 per cent; Jura-Simplon-Railway, 33.1 per cent; Northeastern Railway, 39.8 per cent; Swiss Central Railway, 60.1 per cent; United Swiss Railway, 17.9 per cent. They are also extensively used on the smaller roads, and almost exclusively on the several rack railways of steep grade.

Summary of metal track in Switzerland.

	Miles
Brientz and Rothhorn Rack Railway (1892)	4.71
Burgenstock Rack Railway (1890)	0.62
Gotthard Railway (1894)	124
Jura-Simplon Railway (1890)	102
Mount Generoso Rack Railway (1893)	5.60
Mount Pilatus Rack Railway (1890)	2.75
Northeastern Railway (1890)	41
St. Gallen and Gais Rack Railway (1892)	8.75
Swiss Central Railway (1890)	120
United-Swiss Railway (1890)	1
Viege-Zermatt Rack Railway (1891)	27
Wengern Alp Rack Railway (1893)	12
Total for 1894	449.43
Total for 1890	397.00

BRIENTZ AND ROTHHORN RAILWAY (gauge, 2 feet 8 inches).—This railway is a mountain rack railway for tourist traffic, and is 4.71 miles long with a rise of 5,517 feet, or 237 feet more than a mile. The grades are 20 to 25 per cent, reduced to 5 per cent at stations. The rack is of the Abt system, with two rack bars. The track consists of 40-pound steel T-rails fastened by bolted clamps to steel trough cross-ties 5.9 feet long, weighing 55 pounds each. The chairs for the rack bars are bolted to the middle of the ties. The total weight of the track, including rack bars, rails, cross-ties, and fastenings complete is 220 pounds per yard, and the cost was $20,160 per mile. The engines weigh 17 tons, on 4 driving and 2 trailing truck wheels, with a total wheel base of 9½ feet. The cars weigh 2½ to 5 tons each. The ties are of the usual trough section, with a rib on the lower edges. They are 6 feet long, 5.1 inches wide on top, 8.1 inches over the bottom ribs, 2.54 inches deep inside, 0.25 inch thick on top, and 0.20 inch at the sides. The ends are flared out and bent down, being 3.6 inches deep and 10 inches wide. They are spaced 18 inches apart at the rail joints and 3 feet apart elsewhere. The ties are laid in broken stone ballast, with dry walls at the sides and a bottom course of large stones. The width over the walls is 9.84 feet, and the depth from top of tie to roadbed is 18 inches.

GOTTHARD RAILWAY* (gauge, 4 feet 8½ inches).—The following statement was made to me in April, 1894, by the chief engineer of the road:

At the end of the year 1893 the Gotthard Railway had 124 miles of track with metal ties. Except in long tunnels the ties do not rust, nor is there any measurable wear at the contact of the rail flange and fastening. Cracks in the top table have been noticed only in the ties furnished to us on the basis of our first specifications, and in consequence of these cracks about 2 per cent of the ties laid during the years 1885–'87 have had to be taken out of the main tracks. In long tunnels the metal ties rust severely and wear considerably at the contact surfaces, necessitating the renewal of many of the ties laid on our first trial, but none of those laid since 1887. There is more noise of trains on the metal ties than on wooden ties. Metal ties for switches cost about double the price of oak ties, but the rest of the expense remains nearly the same whether iron or wood is used. The track on wooden ties, laid and maintained by skilled workmen, will show less deviation from the standard gauge than a track on metal ties, when used as well as when not loaded. The deviations from the prescribed gauge, however, can not exceed the permissible amount on metal ties, as long as they are not injured, while on wooden ties the permissible variation may gradually be exceeded.

The soft-wood ties which were in the main track at the beginning of the road have been mostly replaced by metal ties, or by oak ties when single ties had to be renewed. At present we have 66.3 miles of main track laid with oak ties, and 3.72 miles of main track with soft-wood ties on the Cadenazzo-Locarno branch road, while on 18.6 miles of our main track there are oak and soft-wood ties intermixed.

The double tracking of this road, involving the widening of tunnels, viaducts, etc., has been completed, and the second track was opened to traffic in May, 1893. The new track of the Airolo-Faido division is laid with steel rails, 75 pounds per yard and 39 feet long, having 15 steel ties to each rail, the ties weighing 127 pounds each. In the longer tunnels 97-pound rails, 39 feet long, are used, and the rest of the track is laid with 93-pound rails having 16 steel ties under each rail, these ties weighing 145 pounds each.

At the International Railway Congress of 1892 particulars were presented of two test sections each 0.62 mile long, with 1,250 ties spaced 32 inches center to center. One section was laid with oak ties treated with the zinc chloride preservative process, 8.2 feet long, 10 inches wide on the bottom, 6½ to 8 inches wide on top, 6 inches thick, and weighing 154 to 176 pounds. The ballast was of 3½-inch broken stone. The other section was laid with the steel ties shown in my original report, 7.87 feet long (made from plates 8.53 long), and weighing 127.6 to 132 pounds; with rail fastenings 6.16 pounds more. The metal has a tensile strength of 11,020 to 12,122 pounds per square centimeter, with an elongation of 18 to 22 per cent in 8 inches. The ballast was of river gravel, with the largest stones 2 inches in size. Both sections had steel rails weighing 72 pounds and 74 pounds per yard, and were operated by locomotives weighing 85 to 87 tons. The section on wooden ties had 14 passenger and mixed trains and 15 freight trains daily, at a maximum speed of 30 miles per hour, with an annual load of 2,250,000 tons. The section on steel ties had 14 passenger and mixed trains and 12 freight trains daily, at a maximum speed of 46 miles per hour, with an annual load of 1,350,000 tons. From January, 1890, the annual maintenance expenses had been $103.22 to $145.16 per mile for the former, and $64.51 to $80.65 for the latter section. With 2 tie plates and 6 spikes to each tie, the track laid on wooden ties is in good condition after ten years' heavy traffic, and very few renewals had been necessary, while the spikes held well. The metal ties had given entire satisfaction, and are now used exclusively on new work and in the long tunnels, as it is considered that the attachments and maintenance of gauge are more permanently secured, which is a matter of great importance on a line with short curves operated by heavy locomotives having a long wheel base. These ties also have a longer life and a greater value as old material than the wooden ties, while they offer a greater resistance to lateral motion.

JURA-SIMPLON RAILWAY (gauge, 4 feet 8½ inches).—This railway is formed by a comparatively recent consolidation of the Western and Simplon Railway and the Jura, Berne, and Luzerne Railway, both of which were included in my former report. On the former road the first metal ties were of trough section, with closed ends, and of uniform section throughout, but later they were made narrower and deeper at the middle (Pl. 15 of original report). At first they were of iron, but later of mild steel, weighing 99 pounds each. These had gib and cotter fastenings. Since 1891 the company has adopted for its lines of heaviest traffic the form of ties used by the Jura, Berne and Luzerne Railway, weighing 127.6 pounds each, with bolted clamp fastenings, keeping the lighter ties for the lines with lighter traffic. These heavy ties resemble those of the Gotthard Railway. They are of uniform section throughout, are made from plates 8.53 feet long, and are from 4.8 to 9.4 inches wide, with thickness varying from 0.2 to 0.44 inch. The tensile strength is between 83 and 106 pounds per square millimeter. The steel rails are 19.68 to 39.36 feet long, weighing 66 to 67 pounds per yard, and the iron rails are 19.68 to 22.63 feet long, weighing 70 to 72 pounds per yard. The ballast is mainly of screened gravel and broken stone. The number of trains varies from 8 to 35 per day, and the average speed is 25 miles per hour, though on some main lines it reaches 44 miles per hour. The engines weigh from 34 to 67 tons (including tenders), and have a wheel base of 10.8 to 36.74 feet (including tenders). Breakages have a averaged but 4 or 5 ties per year, and are usually cracks at the bolt holes. The following is an abstract of the statement of the maintenance of track for 1890, prepared in 1891 by Mr. Cuenod, chief engineer of track:

The test sections of track with metal and wooden ties have all been selected for unfavorable conditions; that is to say, main lines which present the sharpest curves, steepest grades, and the greatest number of trains. There are 61 sections; 37 with wooden ties, aggregating 17 miles; and 24 with metal ties, aggregating 12 miles. Very different results were obtained on the Western and Simplon Railway and the Jura, Berne, and Luzerne Railway. In 1888 Mr. Mayer, chief engineer of permanent way of the former road, stated that track with metal ties required a little more maintenance work at first, until the track had become firmly settled, after which the cost diminished. While this did not seem to be the case formerly on the latter road, this observation seems to have been confirmed in 1890, although the time is yet

> too short to allow of a definite statement as to the actual economy of metal track. The system of rail fastenings appears to have had little effect, as on the Western and Simplon Railway gibs and cotters were used, while on the Jura, Berne and Luzerne Railway bolted clamps were used; but as on the latter all the nut locks were changed as being too weak, an exact statement of the time actually employed in normal tightening of the attachments can not be made. The most evident result of the comparison of these 61 test sections of track is a positive confirmation of the advantage of screened gravel for ballast. In fact on all the sections, without one exception, all parts on other ballast have invariably been more costly, and have required more maintenance than those on screened gravel or broken stone, on the Western and Simplon Railway as well as on the Jura, Berne, and Luzerne Railway. This result is especially marked for track on metal ties, and to this fact may be attributed the relatively high price on the latter road, while the cost on the two test sections with screened gravel on this road is even lower than on those of the old Western and Simplon Railway, on which the ballast is screened at the same time that ties are renewed. It may therefore be said, without fear of mistake, that if the replacing of sandy or earthy ballast with screened gravel or broken stone ballast, is advantageous for track with wooden ties, it is very much more so for track with metal ties.

The cost for maintenance is about $60 per mile with metal and $97 per mile with wooden ties, this being for labor only, the time of each man being taken (divided as to his work on the rails, ties, attachments, ballasting, etc.), at an average cost of 6 cents per hour.

MONTE GENEROSO RAILWAY (gauge, 2 feet 8 inches).—This is a rack railway on the Abt system, with a two-bar rack. The line is 5.6 miles long, with a rise of 5,203 feet, the grades ranging from 15 to 22 per cent, and 5 per cent at stations. The track is 2.6 feet gauge, laid with 40½-pound T-rails bolted to steel trough ties weighing 55 pounds each. The roadbed is 13.7 feet wide, with a bottom layer of large stones for drainage purposes and 15 inches of broken stone ballast laid between rough dry stone walls. The locomotives are tank engines weighing 25,500 pounds on 4 driving wheels and a trailing pony truck. The cars weigh 10,500 to 11,440 pounds, empty, and seat 48 to 56 passengers. The speed is 3¾ miles per hour on the steepest grades and 5 to 6 miles elsewhere.

ST. GALL AND GAIS RAILWAY (gauge, 3 feet 3⅜ inches).—This line is 8¾ miles long, with about 7¾ miles laid on a public highway, of which 2 miles (distributed in 5 sections) are laid with the Marsh (or so-called Riggenbach) rack rail. The grades range from 9.2 to 15 per cent. The track is laid with 51-pound T-rails bolted to steel cross-ties with attachments of the Baden State Railway type. These ties are 6 feet long, 4.8 inches wide in the middle and 9.2 inches at the ends. The middle portion is flat, but the rail seats are bent up to give the rails a very decided inward inclination (1 in 8), the ends of the ties then being inclined and curved downward. There are 11 ties to a rail length of 29½ feet, spaced 2.72 feet apart, and creeping of the rails is prevented by the use of deep outer splice bars, extending down between the ties. The track weighs 213 pounds per yard, or 348 pounds including the rack. The rack is carried on wrought-iron chairs riveted to the ties and has trapezoidal teeth. At the lower end of the line is a semicircular curve of $98\frac{1}{2}$ feet radius.

VIEGE-ZERMATT RAILWAY (gauge, 3 feet $3\frac{3}{8}$ inches).—This line is 27 miles long, single track, worked partly on the adhesion system and partly on the Abt rack-rail system, the latter being used on grades of 12 per cent. The track is laid with 49-pound T-rails, 34 feet 8 inches long, with 13 steel ties to a rail length, the ties weighing 83 pounds each. The engines weigh 29 tons on 4 driving wheels and 2 trailing truck wheels, the wheelbase being 14 feet 1 inch.

WENGERN-ALP RAILWAY (gauge, 2 feet $7\frac{1}{2}$ inches).—This is a mountain railway on the Abt rack-rail system, about 12 miles long, and was opened in 1893. The track consists of $41\frac{1}{2}$-pound T-rails $3\frac{15}{16}$ inches high, with head $1\frac{13}{16}$ inches and base $3\frac{1}{2}$ inches wide. They are 34 feet 5 inches long, or three times the length of the rack bars. The rails are bolted to steel cross-ties 5 feet 3 inches long, with closed ends, and weighing 59 pounds each. The gage is widened one-sixteenth inch on curves of 656 feet radius, and three-thirty-seconds inch for 328, 262, and 197 feet, while the superelevation is from three-eighths inch to $1\frac{3}{16}$ inches.

STANZERHORN RAILWAY (gauge, 3 feet $3\frac{3}{8}$ inches).—This is a cable railway, 3,959 feet long, starting from Stanz and ascending to within 160 feet of the top of the Stanzerhorn Mountain. It is single track, with a passing place midway, the ascending and descending cars balancing one another. The lower station is 1,476 feet and the summit station 6,070 feet above sea level. The first division starts with a grade of 1 in $12\frac{1}{2}$ (8 per cent) and ends with 1 in 3.7 (27 per cent). The second and third divisions start at 1 in 2.5 (40 per cent) and end with 1 in 1.6 ($62\frac{1}{2}$ per cent). Each section is worked independently. The alinement is mainly on tangent, and the curves are from 492 feet to 1,320 feet radius. The track is laid with flange or T-rails, weighing 40 pounds per yard. They are 32.8 feet long, 4.9 inches high, and have narrow "pear-shaped" heads. They are carried on steel ties of inverted trough section, with flaring sides and triangular ribs on the edges. These ties weigh 51 pounds each, and are spaced 3 feet $3\frac{3}{8}$ inches apart, center to center. There is a tie under the rail joint, and the joints are spliced by angle-bars and four bolts, while four T-headed bolts pass through the flanges of the splice bars, the clamps, and the ties. The other rail fastenings are clamps holding the rail flange and secured by a vertical bolt to each clamp. To prevent creeping on the grades at every fourth rail joint the tie has its downhill side bearing against two vertical I-beams set in a concrete block below the roadbed. On the second and third divisions the ties are of angle-irons 5 by $3\frac{1}{2}$ inches, 5 feet long, laid 3 feet $3\frac{3}{8}$ inches apart. The $3\frac{1}{2}$-inch flange is vertical. The rails and fastenings are the same. This latter construction of track weighs 135 pounds per yard.

SPAIN.

Monistrol and Montserrat Railway (gauge, 3 feet 3⅜ inches).—This is a steep-grade mountain railway, operated on the Abt rack-rail system. It starts from Monistrol, on the Northern of Spain Railway, about 18 miles from Barcelona (in the province of Catalonia), and ascends to the monastery of Montserrat, which is much visited by tourists and pilgrims. The line is 4.8 miles long, with the sharpest curves 213 feet radius, and maximum grades of 15 per cent. The lower station is 632 feet and the summit station 2,360 feet above sea level. The track consists of 40-pound steel T-rails, bolted to steel ties of inverted trough section, with closed ends. The rails are 21 to 31 feet long. The ties are 6 feet long, weigh 59 pounds each, and are spaced 1 foot 6 inches apart at the rail joints, and 3 feet elsewhere. A chair bolted to the middle of the tie carries the two rack bars. The rail joints are spliced by angle bars 22 inches long, resting on the joint ties, and having their flanges notched for the rail fastenings. To prevent creeping, rails are let vertically into the ground at intervals and the ties bear against these. The ballast is of broken stone inclosed by vertical dry walls, 18 inches high, the width over ballast and walls being 10 feet. The engines weigh 17 tons in working order, the load being distributed upon four leading wheels 26 inches diameter (each axle carrying pinions 17 inches diameter, gearing with the rack), and two small trailing wheels. The four leading wheels are loose on the axles, the engines being driven by the rack only. One engine can haul two cars of 11 tons each at 11 miles an hour on the level and 4½ miles per hour on the 15 per cent grades.

PORTUGAL.

General Remarks.*—The Z-bar ties (*see* Belgium) are reported to have been tried on the Royal Portuguese Railway, the Minho and Douro Railway, and the Southern and Southeastern Railway.

DENMARK.

Danish State Railway* (gauge, 4 feet 8½ inches).—In the statement presented by the administration of this road at the International Railway Congress in 1892 it was shown that the Jutland and Fionia Division had 23.56 miles laid with untreated ties of Pomeranian pine and 18 miles laid with 39,000 ties of Martin steel. The steel ties are of trough section, weighing 53.24 pounds, with bolted fastenings weighing 4.2 pounds. They are spaced 18.2 inches at the joints, with a maximum intermediate spacing of 32.4 inches. The general experience is satisfactory, but they are considered to be too small, too thin, and too light, and longitudinal cracks start at the outside fastenings. The wooden ties are 8.52 feet long, 10 inches wide, and 5 inches thick,

SECTION 2.—AFRICA.

GENERAL REMARKS.—In many parts of Africa steel ties are extensively used and with success, while in Cape Colony they are being used to replace the old cast-iron bowl ties. It is notable that these ties are being used on several of the pioneer railways, undertaken within the past few years; and among other reasons for their use in such cases are the facility of track-laying, the resistance to decay and the ravages of insects, and the fact that the metal track is less easily tampered with than that where wooden ties are used. Several of these railways are of narrow gauge.

Summary of metal track in Africa.

	Miles.
Egyptian railways (1894)	862 887
Alexandria and Cairo Railway (1894)	4.25
Algerian railways (Paris, Lyons, and Mediterranean Railway) (1894)	107.50
Bône-Guelma Railway (1894)	2.70
West Algerian Railway (1888)	.14
Massana-Sahati Railway (1890)	14.26
Kayes Bafoulable Railway (1890)	1.75
Dakar-St. Louis Railway (1894)	30
Loando and Ambaca Railway (1894)	5
Kongo Railway (1894)	64
Cape Government Railways (1894)	906
Dutch South African Railway (1890)	40
Delagoa Bay and East African Railway (1890)	42.16
Beira Railway (1894)	75
Mombasa Railway (1894)	50
Island of Reunion (1890)	62
Total for 1894	2,268.76
Total for 1890	1,290.5

EGYPT.

EGYPTIAN GOVERNMENT RAILWAYS (gauge, 4 feet 8½ inches).—The old system of cast-iron pot ties has been practically abandoned, and wooden ties have been largely used in renewals, but Ponsard & Co., of Paris, report that 7,500 Boyenval-Ponsard steel ties (*see* France) have been ordered for a length of 4 miles 1,500 feet on the Alexandria and Cairo Railway, which is double track, 130 miles long. These ties weigh 167 pounds each. The following is a statement furnished to me in July, 1894, by Mr. A. J. Cotterill, deputy engineer in chief to the administration of railways, telegraphs, and port of Alexandria:

From the inclosed diagram you will see that there has been a great increase in the number of wooden sleepers used since 1887, and a corresponding reduction in the pot sleepers used. Pot sleepers were practically abandoned in 1887 for further extensions, and since that date all heavy renewals have been made with Vignoles (or T) steel rails on oak or Turkish pine sleepers. The reason for the above change was that according to the estimates made at that time the cost of a track of this kind was £198 (Egyptian money; £1 sterling English is £0.975 Egyptian) cheaper than a pot-sleeper road. Even in 1891, when the price of cast iron was still lower, the difference was £182 English (say $910) in favor of the T-rails on wooden ties. The cost of cast-iron pot sleepers in 1887 was about £4.500 English (say $22.50) per ton delivered in Egypt; Austrian oak sleepers, £0.240 English each (say $1.20); Turkish oak sleepers, £0.215 English each (say $1.07); creosoted pine sleepers cost about £0.187 (say 93 cents each) and Turkish pine £0.167 English (say 83 cents). A further reason for the change was that ballast was necessary for the line, and our ballast could not be used with the pot sleepers.

All our sleepers, metal and wooden, appear to last an indefinite time when placed in clean, dry, alluvial soil. In damp and salt soil none of our sleepers last well, and it is quite impossible to pack the pot sleepers. Our wood sleepers have not lasted well where the soil was damp and the ballast sandy, or ballast absent. The Austrian oak sleepers laid in 1888 already show serious signs of decay. The Turkish pine sleepers do not last any better under similar circumstances, but the creosoted sleepers fifteen years in the ground have not decayed. In dry soil sleepers last in Egypt at least thirty-five years.

The Vautherin wrought-iron sleepers under double-headed rails are shown in the diagram to have lasted from 1869 to 1892. They were, however, completely unfit for a good road after fifteen years' service. The steel buckled-plate sleepers with cast-iron chairs for double-headed rails were laid down in 1882. In 1888 they began to fail. In 1889 about 2 per cent had completely failed by the chair punching its way through the top of the sleeper, and all the sleepers had lost 40 per cent of their weight. By 1891, that is, in nine years, the last of them was removed from the road. We have thus no steel or iron plate sleepers in our lines at present, but we have just received 6 kilometers (3.72 miles) of steel plate sleepers with saddles (or base plates) for T-rails, weighing 90 pounds per yard. These sleepers were supplied by Messrs. Boyenval & Ponsard (*see* France—E. E. R. T.), and they are of the same section as their sleeper shown in plate No. 6 of your report. They weigh from 167.2 to 169.4 pounds each, and the cost is £0.495 English for ordinary, and £0.520 for joint sleepers (say $2.47 and $2.60 each). As they are to be laid near Cairo and on clean ballast, they will not have the test of damp and salt soil, which is the real test that most of our material has to undergo at present.

The agricultural railways are entirely in upper Egypt where the climate is dry, but I can not give you any details about these lines. Wilson Bey is the engineer of the Dairah-Sanieh.

The pot ties are spaced 1,761 to the mile; oak ties on main lines, 2,097 per mile; pine ties on secondary lines, 2,016 per mile. At the present time there are 1,494 miles of lines and sidings, of which 862 are laid with pot ties and 632 with wooden ties, under double-head and T-rails. Of the track with wooden ties there are 87 miles of creosoted Baltic pine, 192 miles of Turkish pine, and 353 miles of Austrian and Turkish oak. The Vautherin ties declined from 64 miles in 1881 to none in 1892.

A table summarizing Mr. Cotterill's diagram is given below:

Mileage of track of Egyptian railways.

Year.	Total track.	Pot ties.	Wooden ties.
1881	1,122	1,046	112
1882			127
1883			140
1884	1,222		149
1885			161
1886			174
1887	1,238	1,009	189
1888			232
1889			276
1890	1,273	946	315
1891	1,323	976	347
1892	1,409	927	484
1893	1,466	902	565
1894	1,494	862	632

EGYPTIAN RAILWAYS.*—Some of the steel Z-ties (*see* Belgium) are said to have been tried.

ALGERIA.

ALGERIAN RAILWAYS (PARIS, LYONS, AND MEDITERRANEAN RAILWAY)* (gauge, 4 feet 8½ inches).—In 1892, on the track laid with metal ties, there were 85,357 ties of the Vautherin type, covering a length of 53 miles, and 90,686 ties of the Hilf type, covering a length of 54.5 miles. The Vautherin ties are of the dimensions given in my former report, except that the width inside at the bottom is 8.4 inches instead of 7.2 inches, and the flanges are 0.04 inch thick. The joint ties weigh 92 pounds and the intermediate ties 74 pounds, the tie plates and fastenings in each case weighing 10 pounds more. The ballast is of river gravel, clayey and sandy. The defects have been longitudinal cracks at the top corners, owing to insufficient material, and wrenching of the fastenings, due to the use of ill-made attachments. The Hilf ties are also as described, but 5.2 inches wide on top. The tie weighs 95.5 pounds, and the fastenings (not including the base plates) 5.5 pounds. The metal is specified to be of 99 pounds per square millimeter tensile strength, with an elongation of 18 per cent. The ballast is of stone broken to a ring 1.2 inches diameter. No deterioration of the ties has been observed since they were laid in 1885, but transverse cracks occurred in the steel ties 0.44 inch thick on top, though not in the Martin steel ties, 0.56 inch thick. The metal track has more elasticity than the track on wooden ties, and the trains ride more easily upon it, from which it is concluded that it is less severe on the rolling stock. This track is considered very favorable for lines with moderate or light traffic. A metal tie will outlast three oak ties, and the cost of maintenance may be easily reduced to 30 per cent of the cost with wooden ties when the metal track and ballast have been well settled. The Hilf tie becomes unstable after a year or so, as its shape does not admit of proper tamping, and therefore the same number of men must be employed as for track with wooden ties. The annual cost for maintenance in 1888–1890 was $154.42 per mile with the Vautherin ties, $154.42 to $235 with the Hilf ties, and $235 with wooden ties.

The wooden ties are of oak from Algeria and the Pyrenees, "English" oak from Italy, and pine from the Landes impregnated with sulphate of copper. The pine ties are 8.7 feet long and 8 by 5.6 inches section, weighing 154 pounds, and last about four years. The others are 7.8 feet long and 8 by 6 inches section, weighing 187 pounds, and last about eight years. They were laid in broken stone ballast, broken to a ring 2.4 inches diameter. The rails weigh from 68 to 72 pounds per yard. The traffic averages 3,600 trains per year, with speeds of 21 to 31 miles per hour. The engines weigh 26 to 37 tons on a wheel base of 12 to 13 feet.

BONE-GUELMA RAILWAY* (gauge, 4 feet 8½ inches).—In April, 1894, Mr. Kowalski, the engineer, wrote me that there are now 2,500 double-channel steel ties (Boyenval-Ponsard type; see France), and 2,500 of the steel I-beam ties (Severac type; see Belgium). The two systems cover 2.70 miles of track, and were laid between May, 1888, and April, 1889. Owing to the short time of service it was not possible to determine what would be the causes of deterioration, but so far there is no more rusting than with steel rails, which is probably due to the ties having been given a coating of coal tar. The ties are considered to be rather too light and too short, but make an easy riding track. As to the cost of maintenance, the experience is yet too recent to permit of any definite opinion being formulated, but it may be said that up to the present time the sections of track on metal ties have shown some economy over those on wooden ties. In 1892 the annual cost of maintenance was stated at $186.66 per mile for the Boyenval-Ponsard ties, and $273.51 for the Severac ties, the latter, however, being exceptionally high owing to defects in construction. The joint ties are spaced 24 inches and the intermediate ties 36 inches center to center. The Boyenval-Ponsard ties were laid in May, 1888, covering a length of 1 mile, 2,550 feet. They are 7.54 feet long and weigh 123 pounds or 127 pounds including the fastenings. The base plates have inclined seats for the 60-pound T-rails. They were easily laid, held the rails well, and the ballasting was effected as easily as with wooden ties, while the track was firm and smooth. In March, 1890, Mr. Kowalski stated that the ties behaved very well, no breakages of fastenings had occurred, the rails were kept secure, and the cars rode very smoothly. The tamping was done with bars as for wooden ties, and was easier and more solid with gravel than with broken stone. The Severac ties weigh 112 pounds and the fastenings about 2 pounds more. The attachments of these ties when wedged tight, which is indispensable to insure their security, form a rigid fastening which is difficult to displace with a crowbar, and it is necessary first to loosen all the fastenings, which makes the maintenance troublesome. The attachments of the Boyenval-Ponsard ties, while assuring security, have sufficient elasticity to make an easy riding track. The gauge of the outer lugs of the base plates is not exact, and these variations are rectified by placing one or more packing strips 0.04 inch (1 mm.) thick between the rail flange and the lug. Some of the steel Z-ties (*see* Belgium) are said to have been tried also.

The wooden ties used include the following, all of them being 8.2 feet long, 7.6 to 9.6 inches wide, and 5.2 inches thick: (1) Pine, impregnated with sulphate of copper or creosote; these are squared ties, weighing 110 pounds, and have given poor results; (2) Austrian oak, 143 pounds, which is hard but not durable, having grown rapidly in damp earth; (3) oak from the forests of North Algeria and Tunis; this is harder than the Austrian oak and has more compact fibers; the tie weighs 176 pounds; (4) beech from Croatia (Austria), impregnated with chloride of zinc; these have not given such good results as were expected; weight, 143 pounds; (5) eucalyptus; this is moderately hard and very tough, but is liable to twist and warp; the tie weighs 176 pounds. Ties exposed to the hot sun in this dry climate are very soon warped and cracked, and they should be put in the track as soon as possible after being cut. The traffic is from 4 to 10 trains daily, with train loads of 75 to 300 tons, and speeds of 16 to 25 miles per hour. The engines weigh from 30 to 38 tons, with a wheel base of 10 feet on narrow gauge (wooden ties only), and 11.3 feet on standard gauge.

East Algerian Railway.—Ponsard & Co., of Paris, reported to me in April, 1894, that they were negotiating for the supply of 1,200,000 of the Boyenval-Ponsard steel ties (*see* France) to be used to replace the wooden ties in renewals during five or six years.

French Algerian Railway (gauge, 3 feet 6 inches).—The firm of Ponsard & Co., of Paris, has recently reported an order for 900,000 Boyenval-Ponsard steel ties, weighing 89 pounds each, for replacing wooden ties on 500 miles of track. The ties are to be delivered in certain quantities during six years.

West Algerian Railway (gauge, 4 feet 8½ inches).—Early in 1888 there were 250 steel Boyenval-Ponsard ties laid, similar to those of the Bône-Guelma Railway, but 8.2 feet long, and weighing 140 pounds with fastenings. They were laid for a length of 750 feet on curves and tangents and on grades, and also at the Bel-Abbès station, at a point where brakes are applied to stop the trains. The ends of these ties are not closed. In October, 1889, after twenty-one months' service, Mr. Cholet, the manager, stated that they had given good results, held the ballasting perfectly, and had shown no sign of slackening of the fastenings. Some of the fastenings did show signs of abrasion, due to the lateral pressure and motion of the rail flange, and he suggested that this could be avoided by the use of a base plate having a rib on the outer side.

SOUDAN.

Kayes-Bafoulabl Railway (gauge, 3 feet 3⅜ inches).—The Colonial Department of the French Government in 1889 ordered 3,000 of the Boyenval-Ponsard steel ties (*see* France), and they were laid the same year on a length of 1 mile, 3,750 feet. The ties were 5.57 feet long and weighed 55 pounds with the fastenings and base plates for 40-pound T rails. Ponsard & Co. wrote me in April, 1894, that the line is to be extended to Segon-Si Koro, for which they will supply between 600,000 and 700,000 ties.

SENEGAL.

Dakar-St. Louis Railway* (gauge, 3 feet 3⅜ inches).—This railway was completed in 1885, and has a length of 163.76 miles. In 1888 there were 26,900 ties of the Boyenval-Ponsard type (*see* France) rolled by the Société des Denain et d' Anzin for this road, and they were laid during the first half of 1889. They were 5.75 feet long, with base plates for 40-pound T-rails, had open ends, and weighed 80 pounds each, including fastenings. They were laid by negroes at the rate of 984 feet of track per day without interfering with the traffic, which was heavy at the time. The work included opening up the ballast, removing the wooden ties, putting in the steel ties, bolting up the fastenings, and tamping in the ballast. In February, 1890, the manager, Mr. Poindron, stated that the track kept in good condition, and that no difference in sound could be observed between trains running on the track laid with wooden ties and that laid with steel ties. In April, 1894, Ponsard & Co. wrote me that there were then 52,000 of these ties on a length of 30 miles, and that the railway company has resolved to replace all the wooden ties with these steel ties, requiring about 250,000 ties.

The following is an abstract of a report on the life of the ties presented at the International Railway Congress in 1892:

> The track was laid in 1882 to 1885 with 313,000 pine ties impregnated with sulphate of copper, the ties being 5.25 to 5.57 feet long, 6.8 inches wide, and 4.8 to 6 inches thick, weighing about 66 pounds. On these were laid 40-pound T-rails, fastened originally by spikes, but later by galvanized screw spikes. The ties were rapidly destroyed on all the sections infested by the termite or white ant, covering a length of about 43.4 miles, the ties being destroyed in four or five months, or even less. Oak was then tried, but with little success, 56,000 ties being destroyed as rapidly as the pine ties. Toward the end of 1885 about 1,000 creosoted beech ties were laid as an experiment, weighing 72.6 to 77 pounds. These have lasted well, and very few have had to be replaced since 1886, while some which were taken up early in 1889 were found to be perfectly sound and were put back. It is necessary that the wood should be sound, well treated, and free from cracks which would enable the insects to get in and destroy the interior parts less saturated with the creosote. Nevertheless the company decided to have recourse to metal ties, and at the end of 1889 there were 26,857 steel ties laid on sections of 607 feet to 4.65 miles in length, the sections being separated by places where it was considered best to retain the beech ties on account of curves of less than 1,640 feet radius, for which the gauge of the metal tie track was too narrow. The several sections aggregated 14.46 miles. The ties were of double-channel section, 5.57 feet long, 8.8 inches wide, with two riveted base plates giving the inclination to the rail. Two styles of rail

fastenings were used. In the first, each rail is held by the heads of two screws or studs screwed into a tapped washer plate inside the tie. In the second, the rail is held on the outside by a riveted lug the full width of the base plate, and on the inside by a screw bolt bearing on the rail flange. This latter method, while presenting a certain difficulty in track laying, appears preferable to the former, as a greater stability is given by the long rib or lug than by the bolt head. The total weight of tie and attachments is 71.5 pounds in the former case and 76 pounds in the latter. There are nine ties to a rail 25.58 feet long; the joint ties spaced 24 inches and the intermediate ties 36 inches, center to center. The ballast is of sand, sometimes mixed with clay, and is a fairly good material. The traffic varies with the seasons, ranging from one to ten trains per day, while in the busy seasons double-header trains are frequently run. The engines with six coupled wheels and a wheel base of 8.73 feet, weigh 22 tons in working order, and haul train loads of 85 tons (exclusive of the engine) on the grades of 1.3 per cent., and 105 tons on other parts. The speed is from 17 to 22 miles per hour. Washouts occur in the heavy rainstorms and tornadoes of the rainy season from the middle of June to the end of October. Owing to the nature of the ballast it has not been found possible to reduce the section gangs on metal track, but the maintenance is very sensibly less for the metal track. There are no indications of deterioration, the gauge is maintained exactly, there is no displacement of the track, and passengers can find no difference in the riding of the trains over metal or wooden ties.

KONGO (PORTUGUESE).

LOANDO AND AMBACA RAILWAY (gauge, 3 feet 3⅜ inches).—This is the first section of the proposed Royal Trans-African Railway, and it has taken nine years to build the first 160 miles from St. Paul de Loando, while the extension to 230 miles is not expected to be completed before the end of 1895. The cost has been about $20,900 per mile, and all the material has been obtained from Belgium, including some of the Z-bar steel ties.

KONGO FREE STATE.

KONGO RAILWAY* (gauge, 2 feet 6 inches).—The railway now being built by a Belgian company from Matadi to Stanley Pool will be 270 miles long, laid with T-rails on steel ties. In 1890 I visited the Couillet steel works in Belgium to see the Z-bar ties then being made for this road, the railway having ordered a large number with the intention of laying them on the entire length of the road. These ties have been described under the head of Belgium. They weighed 70 pounds each complete, or about 90 pounds when packed with the broken stone ballast. In April, 1894, Ponsard & Co., of Paris, wrote me that 112,000 of the Boyenval-Ponsard steel ties (*see* France), weighing 70 pounds each, were laid in 1889 for a length of 64 miles. They stated also that the railway company had made trials of various types of metal ties, with the result that it had been decided to use the Boyenval-Ponsard ties on the entire line, which will eventually be 300 to 350 miles long. Only about 60 to 100 miles have been completed as yet, and I have not been able to obtain from the railway company any statement as to the ties actually used, but there seems to be little doubt that the whole line will be laid with metal ties. The ballast is said to be of broken stone, obtained from heavy cuts along the line. The rails weigh 47.3 pounds per yard, and the ties are spaced 31½ inches apart. The steepest grades are 4½ per cent and the sharpest curves 165 feet radius. The engines have six wheels, all coupled (with flangless tires on the middle wheels), and weigh about thirty tons.

CAPE COLONY.

CAPE GOVERNMENT RAILWAYS* (gauge, 3 feet 6 inches).—Wrought-iron cross-ties of the Livesey pattern are being more extensively used since 1887, and are gradually superseding the wooden ties in all renewals and extensions. In the report of Mr. Brown, the chief engineer, for the year 1893, it is stated that of 61,505 ties renewed on the Midland Division, 695 miles, 45,514 were metal cross-ties, chiefly used in replacing the old "bowl" or "pot" ties. Metal ties were first tried experimentally in 1881, two types being used: The Livesey trough tie and the cast-iron pot or "terrapin" tie, with each pair of pots connected by a transverse tie bar. The principal objections urged against the trough ties were as follows: (1) Insufficient length, being only 5 feet 6 inches, as compared with 7 feet for the wooden ties; (2) inability to alter the gauge at curves, the keys being always inside the rail and the jaws fixed to gauge so that wooden ties were substituted on curves, involving complication; (3) difficulty of thoroughly and speedily filling the tie with soft ballast, so that the ties rocked and made a bad riding track, while the sides of the tie were injured in tamping. The pot ties had the objections (1) and (3) but not (2), and the keys could be placed inside or outside the rail, thus allowing for widening the gauge on curves. They were subject, however, to other objections, as follows: (4) Multiplicity of parts; (5) transverse weakness, the tie rod with gib and cotter fastenings not being stiff enough to transmit any proportion of load or motion from one pot to the other; (6) inability to pack the two pots of each tie equally, so as to get a uniform bearing; (7) inability to stand slewing in the track. In practice both these types were considered as inferior to ordinary wooden ties, both in ease of laying the track and in keeping it in proper line and surface. They cost from $1.70 to $2 each.

Creosoted Baltic pine ties were first used on these railways at an average cost of $1.08 to $1.32 for ties 9 by 4½ inches and 7 feet long for light rails, and 10 by 5 inches for heavy rails, but experiments were soon made with native timbers. In 1877 a few native ties were creosoted in England and laid on the Western division, and some of these were still in the track in 1887. Yellowwood and stinkwood ties, uncreosoted, decayed with dry rot in six months, while the hardness of the wood made it necessary to bore the spike holes, increasing the cost of track-laying and often damaging the ties. Experiments with creosoted yellowwood, however, proved so satisfactory that in 1885 the Government erected creosoting works at Knysna. In his report for 1893 Mr. Sinclair, chief storekeeper, stated that 83,266 ties had been supplied from these works at a price of $1.26 per tie, 10 by 5 inches and 7 feet long, as compared with $1.32 in former years. These prices must have been profitable, as from January 1, 1894, the price has been reduced to $1 per tie, which is a reasonable rate for creosoted yellow-wood ties delivered at Cape Town, Port Elizabeth, and East London. The tie renewals in 1893 were as follows:

	Miles.	Ties.
Midland division	695	61,505
Western division	864	33,921
Eastern division	331	27,621
Northern division	363	4,837
Total	2,253	127,884
Average renewals per mile		56.7

In July, 1894, Mr. R. E. Brounger, chief resident engineer, wrote me as follows:

> The total length of single track of the Cape Government Railways is 2,267 miles. The total length now laid with wooden sleepers is 1,318 miles, and with wrought-iron transverse sleepers 906 miles. The mileage laid with wrought-iron bowl sleepers has been reduced to 30 miles, and is in process of still further reduction, metal transverse sleepers having been substituted for the bowls, and except on short branch lines they will shortly be eliminated. The cast-iron pots will also shortly be replaced in consequence of the substitution of heavier rails, which the pots will not accommodate. The result will soon be, therefore, that the main lines will be laid exclusively with wood and wrought-iron transverse sleepers.
>
> The colonial yellow-wood sleeper in use is 7 feet by 10 inches by 5 inches, and recent examination has shown that these sleepers, when creosoted, possess very considerable durability (*see* Part III.—E. E. R. T.). Without treatment with creosote, however, they soon decay. The heaviest engines, with tenders, now running on these railways weigh 159,712 pounds on a wheel base of 46 feet 1½ inches, and the maximum weight on a pair of wheels is 27,104 pounds. The ballast generally in use is gravel from the river beds. Broken stone has been used to a very small extent.
>
> In respect to the wrought-iron bowl sleepers, it has been found that the side of the bowls nearest to the center of the track is forced more deeply into the ballast than the outer side, causing the connecting bar to become curved upward near the ends, and resulting in a diminution of the gauge of the road. The bars are ⅝ by 1¾ inches in cross section.

The wrought-iron cross-ties are of the trough type, with rounded closed ends. They are 6 feet 1 inch long over all, 10½ inches wide at the middle, 13 inches wide at the ends, $3\frac{5}{32}$ inches deep over all in the body and $3\frac{17}{32}$ inches at the ends. The ends are horizontal on the bottom corners, but the sides have no ribs or flanges. The metal is seven thirty-seconds inch thick and the weight of tie complete is 79.45 pounds, the rails are of T or flange section, weighing 60 pounds per yard. The outer flange of each rail is held by a riveted clamp 2 by 4 inches, three-fourths inch thick, and projecting three-eighths inch over the rail flange. The clamp is fastened by two rivets and a washer plate is placed between the inner rivet head and underside of top table of tie. On the inner side of each rail seat is riveted, in the same way, a clamp 4 inches lengthwise of the rail and 4½ inches lengthwise of the tie, one-half to five-eighths inch thick. The clamp is flat for 2½ inches and is then bent up to lie over the rail flange. Between the top of the rail flange and the underside of the clamp is driven a wrought-iron corrugated key, 6½ inches long, 1¾ inches wide, five-eighths inch thick at one end and three-eighths inch thick at the other. The corrugations are on the upper face and have a pitch of three-eighths inch. Each key weighs 1½ pounds.

NATAL.

NATAL GOVERNMENT RAILWAYS* (gauge, 3 feet 6 inches).—A committee appointed by the Natal government in 1892 to consider the question of railway ties and the utilization of native timbers reported that it would be better to secure a satisfactory and durable tie of native timber than to contemplate an extensive use of metal ties. In order to thoroughly test the qualities of the timbers, the committee recommended that proposals should be invited for the supply of 1,000 blue-gum sleepers and 500 native-wood ties, to be felled and sawed under the inspection of the forestry department. Then 500 of the blue-gum ties and 500 native ties should be sent to England, where half of each consignment should be creosoted and the others treated by the chloride of zinc (burnettizing) process, then be returned to the colony, laid in the track, carefully watched, and reported on annually by the maintenance department. The remaining 500 blue-gum ties should be stacked and seasoned until the return of the prepared sleepers, and then be laid in contiguity to them. A proposal was laid before the committee for the installation of a small creosoting works in Natal, on certain conditions as to government guaranteeing a contract for ties to a limited extent at a special rate, and it is hoped that the offer may be renewed should it be decided to call for tenders for a small experimental supply; but the committee was not prepared to recommend its consideration at that time.

SOUTH AFRICAN REPUBLIC (TRANSVAAL).

DUTCH SOUTH AFRICAN RAILWAY* (gauge, 3 feet 6 inches).—On this line are laid the Post steel ties of improved design, having drilled instead of punched bolt holes, so as to reduce the liability to cracks at the bolt holes. On wooden ties the Post tie plates, with flat bottoms and with toothed bottoms, have been extensively used.

SELATI (OR NORTHERN) RAILWAY (gauge, 3 feet 6 inches).—This railway starts from Komati Poort, near the western or inland terminus of the Delagoa Bay Railway, and is to extend 200 miles to Leysdorp, a mining center on the Selati River. About 75 miles are now completed and work is in progress. The Ebbw Vale Steel Company, of England, has the contract for track material, including steel ties and T-rails weighing 50 pounds per yard. The railway is being built by the Franco-Belgian Northern Railway Company, of the South African Republic.

BRITISH SOUTH AFRICA.

Beira Railway (gauge, 2 feet 6 inches or 2 feet).—This pioneer railway starts from Fontesville, 35 miles up the Pungwe River from the port of Beira on the southeast coast, and crosses Portuguese territory to the eastern frontier of British territory to open up communication between the Mashonaland gold fields and the coast. It has been completed for a length of 75 miles, and contracts have been let for continuing it to Chimoyo, 45 miles farther, while it is eventually to be extended to Victoria and Salisbury, about 100 miles farther west. The completed portion crosses a section of country infested by the tsetse fly, whose sting is fatal to all beasts of burden, and where, therefore, all freight had to be divided into small packages and taken by native carriers. Steel ties are used throughout.

BRITISH EAST AFRICA COMPANY'S TERRITORY.

Mombasa Railway (gauge, 3 feet 6 inches).—This is a pioneer railway being built by the British East Africa Company, and will extend from the port of Mombasa on the east coast to the Victoria Nyanza. It will be 657 miles long, and the cost is estimated at $17,045 per mile. The maximum grade is 1.5 per cent, compensated for curvature, and the sharpest curves are 573 feet radius. The track is of 50-pound steel T-rails, 30 to 36 feet long, on steel ties weighing 70 pounds each and spaced 32 inches center to center, or 2,000 per mile. Where the soil is salty, however, creosoted pine ties 6 feet 6 inches long and 9 by 4 inches section are used, as on the East Coast Railway of India (*see* India). The steel ties cost $150 to $250 per mile more than the wooden ties, but it has been considered advisable to recommend the general use of steel rather than pyngado wood or creosoted pine for the following reasons: (1) the track is practically indestructible by the natives with such few mechanical appliances as are found in East Africa; (2) the custom of firing the grass at certain periods of the year, and the temptation to steal the timber ties for fuel and hunting purposes; (3) white ants are numerous and commit great ravages (*see* Senegal); (4) the steel ties can not be floated and carried away by floods; (5) it has been shown in India that the cost of laying and maintenance are less with steel than with wooden ties. Ballast is only used in swampy country, and there it is 6 inches thick. The methods of practice of the Indian railways are largely followed.

SECTION 3.—AUSTRALASIA.

AUSTRALIA.

GENERAL REMARKS.—There has been little increase in railway mileage or in the mileage of track laid with metal ties; but the latter fact is not to be wondered at, in view of the many excellent and exceptionally durable native timbers which are available. Nevertheless, in Queensland, the advantages and practicability of metal track for pioneer railways, especially in soft country liable to floods, have been conclusively shown.

Summary of metal track in Australia.

	Miles.
Queensland (1893)	82
South Australia (1894)	152
Total for 1894	234
Total for 1890	186

QUEENSLAND.

NORMANTON AND CROYDON RAILWAY* (gauge, 3 feet 6 inches).—In 1893 there were in service about 82 miles of track laid with the Phillips steel ties, which were described and illustrated in my original report, and are intended specially for use on light and economical railways following the surface of the ground in difficult country.

The railway commissioners, in their report for the eighteen months ending June 30, 1890, stated that the first section of 36 miles, which was built as a low-level surface line, with steel ties and without ballast, was opened in May, 1889, and that the second section, 58½ miles, was to be built in the same way, and to be completed by the end of August, 1890, but that owing to inability to supply the steel ties (contracted for in July, 1889) in time to complete the line by the specified date, some miles were laid with wooden ties. These latter ties, Mr. Phillips states, were sawed ironbark for 7¼ miles, and half-round bloodwood for 5¾ miles, and were liable to attack by the white ants, while it actually costs 49 to 87 per cent more to lay and lift these than the steel ties. Up to the end of June, 1891, only 4,000 cubic yards of ballast had been laid on the entire length of 94½ miles, and only one inspector was employed, so that it is evident that but little supervision was required. As to the cost of maintenance Mr. Phillips states that the cost per mile for the year ending June 30, 1892, was $407.50, which was $124.50 less than the average of the other railways of Queensland, although the wages paid to section foremen were $1.56 to $2 per day on the latter, as against $2.50 per day on the Normanton line. Nevertheless, the railway commissioners have expressed considerable dissatisfaction with the steel ties, but from the objections raised in their reports and by some of their engineers, and from Mr. Phillips' replies thereto, I am free to confess that the evidence appears to show very strongly that the steel ties gave good results, and that the objections were not well founded. As already explained at length in my original report, the line is one of economical construction across bad country subject to floods, but many of the objections against it are such as might apply if it was a road of heavy and important traffic, and I have frequently had occasion to observe that colonial railway men and engineers do not sufficiently appreciate the advantages of light railways or the principles of building economical railways suitable to the traffic, but have a tendency to build heavy and expensive roads on English standards, and to consider light railways as in themselves dangerous and objectionable. Mr. Phillips has strongly advocated the construction of light railways, of moderate cost as pioneer railways (which is exactly the kind of railway largely needed in Australia, and a move toward which has recently been taken in New South Wales), but considers it immaterial whether wooden or metal ties are used, though the latter are advantageous and economical where timber is scarce and white ants are numerous. There can be no question, he thinks, that the deep trough steel ties make a better track than the wooden ties, particularly upon such soft and "rotten" or treacherous country as is traversed by this railway. This he expressed as follows in a letter to me in March, 1890:

> Without it (the steel tie) I could never have done the work I have, especially on the ground I had to deal with. By its means I have built, worked, and maintained 36 miles of the description of railway I advocate, and in spite of a rainfall of nearly 60 inches in three months, of which 20 inches fell in seven days, the line is still above ground and working, although the ground has been so inconceivably soft and rotten that it would, to use a local expression, "bog a duck."

The steel ties were originally laid and packed with about half their depth below the original surface of the ground, with a little earth banked up against the ends. After the first heavy rains the track settled to a bearing practically upon the normal surface of the country, thus presenting no interference to the drainage and requiring very little surfacing or raising afterwards. But a later engineer, imbued with the idea that ballast is absolutely indispensable, actually lifted these ties so that the interior core of earth was above the normal surface and would be at once softened by rain or washed out in case of flood, while in dry weather it crumbled and blew out. Complaint was made of corrosion of the ties in ground impregnated with salt, and some ties were taken out after four years' service, but Mr. Phillips states that while the lower flanges were somewhat rusted the top table was but slightly affected, while the riveted fastenings were in good condition and the ties were not cracked or buckled in any way, being in condition for further service. It was estimated that with such results under such conditions of soil, the ties would last from twelve to thirteen years in such soil. They were specified to be of Bessemer or Siemens-Martin steel, with a tensile strength of between 26 and 30 tons per square inch, an elongation of 20 per cent in 8 inches, and to bend cold without fracture to an angle of 100 degrees across the grain or 120 degrees with the grain. These plates were pressed to shape cold, and up to the end of 1892 not one had been removed owing to fracture, while two which were deformed through large stones being left under them in tamping showed no signs of fracture. The following is an abstract of Mr. Phillips' reports, made in August, 1891:

The first 36 miles are laid with steel ties, 5 feet 9 inches long, 10 inches wide, and 5 inches deep, weighing empty 84 pounds, but when packed with soil or gravel (which adheres to the tie under compression and assists by its inertia in steadying the track) the weight is increased to 273 pounds. These were manufactured in Brisbane from imported plates at a cost of $2.30 each, delivered at Normanton. Steel ties 6 feet by 10 inches by 5 inches are laid for 45 miles, weighing 100 pounds empty and 297 pounds when packed; these were manufactured in Glasgow at $42 per ton, f. o. b., which, with freight and other charges added, brings the total cost to $2.50 for each tie delivered at Normanton. Sawed iron-bark ties, 6 feet 9 inches long and 9 by 3½ inches section, weighing 102 pounds each, are laid on 7¼ miles. They cost $1 each delivered, while full size ties (4½ inches thick) cost from $1.75 to $2. The remaining portion of the line, 5¾ miles in length, is laid with half-round bloodwood ties 6 feet 9 inches long and 9 by 4½ inches section, weighing 102 pounds and costing $1.12. The number of ties per mile averages 2,234 steel, or 2,640 wooden ties, with about eleven steel or thirteen wooden ties to each rail. The last 25 miles were laid and lifted in sixty-four working days at an average rate of 2,062½ feet per day. The greatest length on any one day was 2,640 feet of wooden-tie track, with 87 men, at a cost of 8¼ cents per foot for labor, and 3,430 feet of steel tie track, with 76 men, at a cost of 5½ cents per foot for labor. The cost of labor in the former case was 48.8 per cent higher than in the latter; but on long lengths of line I have found that the wooden ties cost 87 per cent more to lay and lift than the steel ties. The weight of first-class track in Queensland, with 60-pound rails, is 310 pounds per linear yard, while on this road the weight per yard is 242 pounds with the wooden ties and 432 to 463 pounds with the steel ties (including their packing). The cost of maintenance per mile per annum was $510, or 62 cents per train mile, with a traffic of 63,220 gross tons. The minimum wages are $2.50 per day and at the lowest rate of $1.56 on other parts of the railways of the colony the cost would have been only $332. The number of men employed averaged 0.65 per mile.

During the wet season (January to April, inclusive) 11¾ miles in the vicinity of the Norman River were submerged for some time at an average depth of 6.4 feet, and a maximun of 16.42 feet over the rails, while the Norman bridge could not be crossed for several weeks, but trains were run up to the flooded portion and mails and passengers conveyed across by boats, the highest traffic return for any one month ($5,837) being during this season. This proves that the road is capable of doing fair average work during the worst weather, and that it can not be regarded as a fair-weather road only. Although the damage done by the flood was inconsiderable, and trains were able to resume running wherever the bridges were uncovered, the fact that the section from Haydon to Patterson was opened in an unfinished condition at the beginning of the wet season has added considerably to the cost of maintenance.

Bringing the matter of this interesting experiment up to date, I give below the substance of a communication furnished me by Mr. Phillips in June, 1894.

The Normanton Railway, on which my system of steel ties was laid, was taken out of my hands by the Queensland railway commissioners as soon as the construction of the line was completed, in October, 1891. Since then I have not been in a position to exercise any control over the line in any shape whatever, and I am therefore at a disadvantage not only in giving the particulars you ask for, but also in watching over the initial stages of an experiment which was authorized by a late government of the colony, on my representations.

The length of main line laid with my system of steel ties is about 81 miles, and about 2 miles of sidings in addition. The length of service has been from three to six years, but with the exception of a few ties laid in ground highly impregnated with salt, the sleepers as a whole are not showing signs of decay. The system has answered the purpose I had in view, namely, to secure at minimum cost a road over which ordinary rolling stock can run at moderate speed in any weather, so long as the rails are not too deeply covered by water. No part of the track laid with metal ties, whether ballasted with stone or earth, has ever failed to do the work required from it, although the country is extraordinarily soft in wet weather, and subject to a heavy rainfall for three months in the year, and great dryness of climate during the other nine months. Mr. H. C. Stanley, the chief engineer of Queensland railways, who has always been opposed to my methods of construction, contends that "a thoroughly drained and well-ballasted roadbed is essential to secure a permanent and economically maintained line of railway." By "well-ballasted" he means from 1,000 to 1,200 cubic yards of good, clean, broken stone or river shingle (small water-worn stones with a small quantity of clean sand) per mile of single line. By "well-drained" he means a road with the formation (subgrade) so raised above even ground or so graded in uneven ground, and so protected by side and cross drains, that flood or storm water shall never come in contact with the ballasted roadbed. The average cost of this kind of railway in Queensland has been $34,200 per mile, including rolling stock, and for the year ended on June 30, 1893, resulted in a loss on working all Queensland railways (2,373 miles) of $2.96 per head of population, estimated at 430,000 souls. In the loss on working I include interest as capital expended on open lines at 4 per cent per annum. For the same period, and subject to the same limitations, the loss in connection with the Normanton Railway, 94 miles, amounted to 3¼ cents per unit of population.

The first cost of steel sleepers in Queensland has hitherto proved more than double that of wooden sleepers, but this is largely due to purchasing steel plates or manufactured steel sleepers on an inflated metal market. In certain cases I am confident the first cost of the former need not exceed that of the latter. The steel ties have not corroded to any serious extent except in one place (5 miles) where they were laid in ground highly impregnated with salt. From the experience I have had with metal sleepers in the track, now extending over seven years, I do not think it necessary to use any preservative coating, except to protect sleepers in transit by sea, and then an oil bath would answer all the purpose. The only cracks I have noticed have occurred at the foldings of the metal, and are due to defects in rolling the plates. None have cracked at or near the rail seats or fastenings. There are no complaints as to wear, but the traffic is very light and the length of service of the steel ties only from three to six years. Steel ties properly packed and well boxed up with stone or earth ballast are not more noisy than wooden ties under similiar conditions. My fastening is a riveted clip (two rivets) to hold the outer flange of the T-rails, and a loose clip, secured by a bolt, to hold the inside flange. I have heard no complaints of the fastenings and have very seldom noticed any rattling when traveling over the road. If the bolts that hold the inside clips work loose, the fact is at once observable from the rattling sound.

I was over the road twice, from end to end, within the last seven weeks. As a member of the legislative assembly of this colony for the electoral district of Carpentaria, which includes the greater portion of the Normanton Railway, I had occasion on April 30 to travel over a portion of the line, and on May 2 and 3 I traveled from end to end in company with Mr. Lloyd Hassell, the officer in charge of traffic and maintenance. I found that the Railway Department has more or less fully ballasted with stone the 13 miles of wooden ties, presumably with the idea of minimizing the damage to the ties from the attacks of termites (white ants). In spite of this protection they are being rapidly destroyed. I also found that the department is proceeding to generally ballast the road with stone or river shingle, but it will take some years before the line is thoroughly ballasted in this way. I found the road in good order and condition, and although the train was the monthly pay train stopping at every gang of lengthsmen (section gang) in addition to the ordinary stopping places, the 94 miles were accomplished in 5½ hours. It was a mixed passenger and freight train. I found a growing conviction among those employed on the line in favor of the steel ties.

In conclusion, it is important to bear in mind that only in a very few places (certainly not more than 2 miles out of 94) were any side or cross drains provided by me when constructing the railway. The drainage of the line remains the same to this day. It is practically undrained by any artificial method except at the crossings of creeks, where low-level bridges are provided. In wet weather no part of the country traversed between 14 miles and 90 miles will sustain the weight of a man on foot without his sinking at every step as far as the knee and often much deeper. Steel ties are used only on this railway. For future railway extension in this colony I do not propose to further advocate the use of metal sleepers. The work already done is sufficient to ultimately demonstrate the relative advantages of steel and wooden sleepers in the northern parts of Queensland, and the question can safely be left to settle itself.

Railway.	Length, in miles, open June 30, 1893.	Cost per mile open, including rolling stock, to June 30, 1893.	Cost of maintenance per average mile maintained, exclusive of relaying.		Wages of section men, per day.*	Average number of men per mile 1892–'93.
			1891–'92.	1892–'93.		
Normanton	94	$14,380	$407.35	$388.46	$2.50	0.45
All railways	2,373	34,200	531.84	510.82	1.56 to 2.50	0.75

* The Normanton Railway is the only one on which laborers are paid $2.50 per day.

In April, 1894, a report on this railway was made to the chief engineer of railways by Mr. Lloyd Hassell, officer in charge, and this report was as follows, with appended explanations by Mr. Phillips:

Steel sleepers with ballast.—There is a great difference in the quantity of ballast used with these sleepers, running from a bare sprinkling to, in a few cases, an ample supply. Some are packed, and even at a few spots boxed up, with ballast, while the great bulk are packed in the centers and boxed in with earth, the ends only being packed with ballast. The continuous wet, lying as dead water in some cases for over two months up to the top of the sleepers, has caused the sleeper and packing to work, and made a bad top on the road, but, speaking generally, the ballasted steel-sleeper road has maintained a better top and line than I would have thought possible in such country, even with the limited traffic, viz, 4 to 6 trains a week throughout the wet season. [The term ballast refers to broken stone or river shingle, with an admixture of clean sharp sand. The wet season referred to commenced early in January and lasted to nearly the end of April of this year. The recorded rainfall at Normanton was over 50 inches in that period.—G. P.]

Steel sleepers without ballast.—The "layer" part of this road is between 6 and 14 miles, 15 and 36 miles, 60 and 70 miles. I examined that between 60 and 70 miles on the 2d instant. Much of it is in more or less bad repair, and at some points trains have to be slowed. The tops of the sleepers in many cases are flush with the ground. In such places, where the water is lying on the ground and the road for a short length begins to work vertically, there are no means of repairing it properly without ballast. Earth and even sand packing to a modified extent are "squirted" out of the sleepers by every passing train. [By "layer" Mr. Hassell means those parts of the road on which no stone or shingle ballast has been used. The part of the road from 60 to 70 miles has never experienced any wet weather to speak of from the time it was first laid, in 1891, until the wet season of January to April, 1894, the wet seasons of 1891–'92 and 1892–'93 having missed. The other parts referred to were maintained by me throughout two very heavy wet seasons—1889–'90 and 1890–'91—and the ground had become thoroughly consolidated. It is worthy of note that the officer in charge makes no comment on those parts. I traveled over the line in May with this officer before there had been time to ballast with stone the length between 60 miles and 70 miles, and the train ran to time and was not slowed. Certainly the ground had dried up a good deal in the meantime.—G. P.]

Wooden sleepers with ballast.—Where there was ample bottom ballast and well boxed up, the road has kept in perfect repair, but where the under ballast has been unduly reduced in quantity the road has got into bad repair. [When I was laying the 13 miles with wooden sleepers I ballasted the whole of it with stone or shingle to the extent of about 100 cubic yards per mile. Since the line was taken over from me by the railway department in October, 1891, this portion of the road has been pretty fully ballasted and boxed up with stone or shingle throughout.—G. P.]

Generally.—In my opinion the steel-sleeper road compares very favorably with the wooden-sleeper road for its power of resisting derangement with a limited quantity of ballast in a flat country road in a wet season, but if the soil passed through is not in itself a natural ballast it would seem to be quite necessary to provide at least sufficient ballast to pack the sleepers fully wherever water is liable to lie on the surface. [It should be borne in mind (*a*) that the steel sleepers are only 5 feet 9 inches to 6 feet in length by 10 inches wide at the bottom, as compared with a length of 6 feet 9 inches and width of 9 inches for wooden sleepers; (*b*) that only 11 steel sleepers are provided to a 26-foot rail, as compared with 13 wooden sleepers; and (*c*) that the steel sleepers are, if ballasted with stone at all, only very lightly ballasted, whilst the wooden sleepers are generally fully ballasted and boxed up with stone. The country traversed by the Normanton and Croydon Railway is the most unfavorable for the purpose that I am acquainted with in Australia, and I have had over forty years of colonial experience.—G. P.]

NEW SOUTH WALES.

NEW SOUTH WALES GOVERNMENT RAILWAYS* (gauge, 4 feet 8½ inches).—I am informed by Mr. W. T. Foxlee, engineer in chief, that steel ties have only been tried to a very limited extent, those invented by Mr. Cowdery, and mentioned in my original report, having been the only ones tried. These ties were found very unsatisfactory and were removed after being in the track about two years. I am indebted to Mr. Foxlee for the following statement as to the track of these railways:

All classes of colonial hard-wood timbers have been tried for sleepers, but we have found that ironbark is by far the best. This timber, which weighs about 80 pounds per cubic foot, lasts in the road about twenty-five years, and when the timber is of exceptionally good quality, even a longer period. We find the ironbark obtained from the coastal districts somewhat superior to that grown inland. Red gum has been used to a limited extent, and is a first-class timber, though not equal to ironbark. The best timber is that grown in the valley of the Murray River and other places subject to floods. Jarrah, which is indigenous to Western Australia, has not been used for sleepers in this colony, but from samples I have seen I do not consider it equal to ironbark. Our sleepers are rectangular in form, the standard size being 9 feet long, 10 inches broad, and 5 inches deep. These sleepers are spaced 2 feet 7 inches center to center, and at the joints, which are always kept opposite, the spacing is 1 foot 8 inches center to center.

The 80-pound bull-head rail is used only on the suburban line, where the traffic is exceptionally heavy. The 80-pound T-rail is now our standard rail for all main lines. The 71½-pound T-rail is used on branch lines where the traffic is important; and the 60-pound T-rail on other branch lines where the traffic is light. With regard to ballast, on the greater portion of our lines broken stone is used. On the more important lines, bottom ballast of 4 inches gauge is first put down, and upon this a top ballast, consisting of basalt, limestone, quartz, or other hard stone broken to 2½ inches gauge, is spread and packed under the sleepers. The spaces between the sleepers are also filled in and the surface lightly covered with ballast. On lines where the traffic is not heavy the ballast is generally hard stone broken to a 2½-inch gauge, and laid to a depth of from 5 to 8 inches under the sleepers, these latter being boxed up as mentioned above. The length of line now open (May 11, 1894) is as follows:

	Length.		Equivalent in single line.	
	Miles.	*Feet.*	*Miles.*	*Feet.*
Quadruple line	8	2.788½	34	594
Double line	149	2,772	299	264
Single line	2,304	1,831½	2,304	1,831½
Total length of track			2,637	2,689½

SOUTH AUSTRALIA.

SOUTH AUSTRALIAN GOVERNMENT RAILWAYS* (gauge, 5 feet 3 inches and 3 feet 6 inches).—As noted in my original report, 27 steel ties have been laid as an experiment on the broad gauge line in the station yard at Adelaide, where they have been subjected to heavy traffic. Mr. A. B. Moncrieff, engineer-in-chief, writing in July, 1894, states that the ties were first laid on April 19, 1886; taken up for examination on September 24, 1887, after 75 weeks' service. They were relaid on October 1, 1887, and finally taken up on May 29, 1888, making in all 105 weeks that the ties were under trial. Up to the date of first examination the traffic amounted to 3,778,261 tons on the up line (15 ties), and 2,551,441 tons on the down line (12 ties). Several showed slight cracks or flaws at the rail seats, and the majority were slightly rusted. They were evidently insufficiently stiff longitudinally, as 25 were bent upwards from the rail seats to the ends, the extent of the bend being from "slightly" to three-eighths and three-fourths inch. One tie was rejected for a crack half through the tie, and was not relaid. Up to the date of the second examination the traffic amounted to 5,289,565 tons on the up line, and 3,572,017 tons on the down line. Only a few more slight cracks were noted, and the rusting and bending were about the same as at the time of the first examination. Two ties were reported as too badly cracked to be relaid. The ties were of very light construction, and of approximately similar type to the narrow-gauge ties in the same colony (Pl. 18 of original report), but were not corrugated. They were 8 feet long, 13½ inches wide at the middle, and 16 inches wide at the ends, a flat flange surrounding the trough part of the tie. The depth was 3 inches, and the metal was $\frac{3}{16}$-inch thick. The cross-section resembled section B-B on Pl. 18. Five types of rail fastenings were tried: (A) A U-bolt with one end forming a clip to hold the outer rail flange, the other end vertical, with a nut and clamp, and the horizontal leg within the tie bent so that only the middle bears against the underside of the top of the tie. (B) and (E) Two bolts with nuts and clamps, the heads of the bolts being inside the tie and engaging with a washer plate. (C) A U-bolt with horizontal leg and two vertical ends with nuts and clamps, as on plate 18. (D) Similar to the latter, but with the leg bent so that only the middle bears against the tie.

Palmerston and Pine Creek Railway.—On this narrow gauge (3 feet 6 inches) line, in the northern territory of the colony, there are 144 miles of main track and 8 miles of side track laid with 41¼-pound steel rails and the steel ties described in my original report. These ties are giving entire satisfaction under the light traffic of this line. In July, 1894, Mr. A. B. Moncrieff wrote as follows in regard to these ties:

> The laying of these sleepers was spread over a period of two years, and the work was completed five years ago. Up to the present time only three sleepers have been taken out of the line, and these were crippled through bad packing on the abutment of the bridge. There has not been a crack discovered in a single sleeper yet. The pickling or coating has worn off in places and there are patches of rust appearing, but not so much as might have been expected in view of the very hot, moist climate which obtains in the northern territory. The fastenings have also proved satisfactory and have given no trouble. You will have noted that they do not provide for widening the gauge on curves, but in the particular case in which we used them this was not found necessary. There is certainly more trouble in lining up the road with these sleepers than with wooden ones, as the ballast gets set hard in the hollow bottom of the sleepers and has to be broken away before a new bed can be made. But, on the other hand, the steel sleepers have a much better hold on the ballast and, when once properly lined up, with light traffic there is very little shifting.
>
> The best ballast for use with sleepers of this shape is a very sandy gravel for bottom ballast, and a coarse gravel or broken stone for the top ballast. The traveling over these steel sleepers is certainly more noisy than with wooden ones, but it is reported that it does not cause any inconvenience. At first the maintenance of the line was more costly in the wet season than in the dry, but now that the banks are set there is no appreciable difference. As far as the bending of the sleepers is concerned, this can only arise in case of the ground being softer under one rail than under the other, but we have had no experience of such a state of affairs. We had some heavy washouts in 1891, but found that the steel sleepers were very easy to handle. As will be seen from the drawing (Pl. 18), they are so light that they had not even to be removed from the rails. The fishplates were taken off and the rails and sleepers were moved in sections. I have had a large experience in dealing with washaways with wooden sleepers, and, as a rule, no such arrangement as this is possible, so that in the use of steel sleepers under these circumstances there is a very decided advantage.

Practically we have had no renewals. It is therefore impossible to say what will be the average life even of these light steel sleepers. It is admitted that the traffic has been light, and even with the material for construction which was carried over the first part of the line, it is calculated that not more than 120,000 tons have passed over any one joint since the opening of the line. You will therefore see that upon the very important point of the life of the sleepers I am not able to speak positively.

Alongside these steel sleepers we used timber on bridges, and under all switches and crossings. The timber used is chiefly jarrah. A large number of these wooden sleepers have already failed, many having perished from what is known as "wet rot." The annual rainfall in the northern territory is about 60 inches. The country is also infested with white ants, so that if the line had been laid with wooden sleepers, even of our splendid hardwood timber, it is exceedingly likely that during the number of years which have elapsed since the commencement of the work the whole line must have been resleepered.

VICTORIA.

VICTORIA GOVERNMENT RAILWAYS (gauge, 5 feet 3 inches and 3 feet 6 inches).—As the forests of this colony furnish a practically unlimited supply ot high class timber, metal ties of any kind have not been used, and nearly all the railways are laid with ties of grey box, red ironbark, or red gum, as shown by the following statement prepared from information sent to me in May, 1894, by Mr. T. Rennick, engineer in chief:

Grey box (*Eucalyptus polyanthema*); life, 27 years. Red ironbark (*Eucalyptus paniculata*); life, 25 years. Red gum (*Eucalyptus rostrata*); life, 18 years. Ties of these woods cost from 60 cents to $1.20 each. Blue-gum and Messmate ties (*Eucalyptus globulus and Eucalyptus obliqua*) have been used in a few instances, but have not proved satisfactory. Their life is 5 to 12 years, and their cost is 40 cents to 85 cents each.

The Melbourne and suburban lines, with two to four tracks, have ties of the first three timbers, 10 by 5 inches section, 9 feet long, the intermediate ties spaced 3 feet apart and the joint ties 2 feet apart. Steel T or flange rails, weighing 75, 80 and 100 pounds per yard, are used. The ballast is 8 to 10 inches thick under the ties, boxed up to 12 to 14 inches. The heavy main country lines, with two tracks, have similar ties and ballast, but with 75 and 80 pound steel T-rails and 75 and 80 pound iron and steel bull-headed rails. Single track, main and branch lines, have similar ties, some, however, being 9 by 4½ inches, 9 feet long, and others 9 by 5 inches and 10 feet long. The ballast is 6 to 10 inches thick under the ties, boxed up to 12 to 14 inches. Rails weighing 50 pounds per yard were tried for the country lines, but have been replaced with 60-pound or heavier rails. The rolling stock includes cars with the European system of four or six wheels and a rigid wheel-base, and also cars with the American system of trucks or "bogies." The former weigh from 4 tons, with 4 wheels and 7 tons capacity, to 12 tons for a six-wheel passenger car with seats for 46 passengers. The latter weigh from 10 tons for a car of 15 tons capacity on four-wheel trucks, to 32 tons for corridor cars with six-wheel trucks and seating 70 persons.

SECTION 4.—ASIA.

INDIA.

GENERAL REMARKS.—In India metal track is used to a very much greater extent than in any other country, nearly 50 per cent of the railway mileage being laid with such track, while the percentage shows a steady increase, due to the replacing of wooden ties with metal. The earliest forms were the cast-iron bowls or pots used in Scind, and these made a smooth and excellent track in sand ballast and under slow speed trains, but with the increase in speed the breakage of the bowls increased considerably. Some of the main lines, however, still use ties of this type, having improved the design of the bowls so that they are found to be very satisfactory under modern conditions of train service. The flat-bottomed cast-iron plate ties of the Denham-Olpherts pattern are also found to be far more satisfactory than might be supposed, and are practically indestructible, while rust or corrosion, of course, do not affect cast iron to any appreciable extent. With ties of this type, however (i. e., a pair of bowls or plates connected by a tie rod), great care must be exercised in tamping so as to get both bowls or plates equally well supported, as otherwise a distortion of the tie rod or fracture of one of the cast-iron pieces is likely to result. The stamped steel trough ties of the Rendel type (known in India as the pea-pod type) have been very extensively used and with success, the fastenings especially being simple and efficient. The principal objection appears to be their liability to rust or corrode, particularly in salty soils, which may seriously affect the life of thin, light ties used on the less important railways. Large numbers of the cast-iron ties are made in India, but all the steel ties are imported, mainly, if not exclusively, from England.

As a proof of the extensive and continued use of metal ties and of the commercial importance of their manufacture, I give the following partial list of additional contracts awarded since the date of my original report, premising, however, that it is very far from complete and merely serves as an indication of the extensive use of such ties:

Bengal Provincial Railway.—Steel ties and 30-pound T-rails, February 28, 1893.

Great Indian Peninsular Railway.—Cast-iron ties. November 16, 1893.

Indian Midland Railway.—Cast-iron ties with tie bars, gibs, cotters, pins, and felt resting pieces for the rails September 20, 1894.

Indian State Railways.—Steel ties, February 4, 1892; October 31 and December 28, 1893; January 9, (9,000 tons) and May 8, 1894. Cast-iron ties, March 1, 1892, and April 17, 1894. Tie bars, gibs, and cotters February 2, 1892.

Madras Railway.—Cast-iron pot ties, tie bars, gibs, and cotters, October 23, 1891; cast-iron pot ties, May 18, 1893.

South Indian Railway.—Steel ties, with keys, 36,000, October 6, 1891. Cast-iron pot ties, 2,387 tons, February 9, 1892; 2,816 tons, May 2, 1893.

Southern Mahratta Railway.—Steel ties, 18,000 for 41½-pound T-rails, November 28, 1893; 555 tons, December 20, 1893; 1,232 tons, January 9, 1894.

Summary of mileage of metal track in India.

Railway.	Date of report.	Denham-Olpherts plates.	Bowls.	Steel cross-ties.	Total metal track.
		Miles.	*Miles.*	*Miles.*	*Miles.*
Amraoti*	1890		5½		5½
Bengal and Nagpur	1894			862	862
Bengal Provincial	1894			30	30
Bezwada Extension	1893			100	100
Bhavnagar-Porbandar	1893			69¼	69¼
Bina Guna	1893			73½	73½
Bombay, Baroda and Central India	1894		165½		165½
Calcutta Port*	1890		12		12
Cherra Companyganj*	1890			7½	7½
Delhi, Umballa and Kalka	1894	162			162
Dhond Manmad*	1890		145		145
East Coast	1894			160	160
East Indian	1894	1,350	113		1,463
Eastern Bengal	1894	135	21	24	† 190
Gackwar's Mehsana	1893			52½	52½
Gackwar's Petlad	1893			13¼	13¼
Godhra Rutlam	1894			100	100
Great Indian Peninsular	1894		1,632		1,632
Indian Midland	1894	40	500	50	590
Indian State	1894	360	225	2,113¼	2,698¼
Jodhpore Bickaneer	1893			300	300
Jorhat*	1890			3	3
Khamgaon*	1890		7½		7½
Kolhapur	1893			29	29
Madras	1894		830		830
Morvi*	1890			90	90
Mushkaf Bolan	1894			65	65
Mysore Goldfields	1893		10		10
Nizam's	1893		62	268	330
Northwestern	1893	370	40	636	1,046
Oudh and Rohilkund	1893		675	35	710
Pondichery	1893		¼		¼
Rajputana Malwa*	1890	50			50
South Indian	1894	47	638	348	1,033
Southern Mahratta	1893			620	620
Total for 1894		2,514	5,001½	6,029½	13,655
Total for 1890		1,714½	3.958	3,912¼	9,224½

* These figures are taken from the former report.

† The total for the Eastern Bengal Railway includes 10 miles of miscellaneous metal ties.

AONLA AND BUDAON RAILWAY (gauge, 5 feet 6 inches).—This is a projected line 19 miles long, forming a branch of the Oudh and Rohilkund Railway. It is proposed to lay it with new steel 60-pound rails on steel trough ties, or with second-hand steel 60-pound rails on wrought-iron saddle ties taken out in renewals on the main line. The cost in the former case is estimated at $20,500 per mile.

BENGAL AND NAGPUR RAILWAY* (gauge, 5 feet 6 inches).—This road has now 862 miles laid with the Rendel steel ties, and Mr. T. R.

Wynne, chief engineer, wrote me in May, 1894, that he had nothing further to state about these ties beyond the information given in my original report, as the line was only opened in 1891, and he has not yet had sufficient experience to say whether the ties will have a long life. The 75-pound steel T-rails on steel ties make a very excellent and smooth-running track, which is easily maintained. There are no cast-iron or bowl ties on the road. An interesting work carried out in 1888 was the change from the meter gauge to the Indian standard gauge of 5 feet 6 inches, and as the work involved operations in the handling of metal ties which may occur under other conditions, I give the following abstract of a description by Mr. George Moyle in a paper presented to the Institution of Civil Engineers in 1891:

> The meter-gauge line was laid throughout with flat-footed or T-rails, weighing 40 pounds per yard, on wooden cross sleepers 6 feet long; the new standard-gauge permanent way consisted of steel flat-footed rails weighing 75 pounds per yard on steel sleepers of the inverted trough pattern, with lugs punched out of them under which the foot of each rail was held by steel keys tapered and split. These sleepers, which weighed about 120 pounds each, were, for the purpose of conversion of gauge, manufactured with four pairs of lugs each, the outside pairs to hold the 75-pound and the inside pairs to hold the 40-pound rails. A mixed-gauge line, consisting of four rails, was thus easily laid; but, in consequence of the steel sleepers being spaced a yard apart throughout to suit the standard gauge, the meter-gauge line, which required to be supported at intervals of 2 feet at the joints and 2 feet 9 inches apart elsewhere, could not be maintained in the best order for the running of meter-gauge trains. At the rail joints of the meter-gauge line, which were not evenly supported between the steel sleepers in consequence of the 40-pound rails being 24 feet long while the 75-pound rails were 30 feet long, it was found necessary to lay some of the old wooden sleepers. Wherever diversions were necessary at bridge operations, the wooden sleepers which had been removed from the old line, and the 75-pound rails temporarily idle in the mixed line were made use of. There were altogether 62 diversions of a total length of 18 miles, all the more important of which were opened by the middle of February, 1888. It is satisfactory to be able to state that, although as many as twelve and fourteen trains passed over the line in a day, no accidents, and only a few detentions were due to track-laying operations. The new permanent way materials were distributed along the line by meter-gauge trains, so that everything was ready to hand for carrying out the operation of laying described below. The inspector in charge at a "rail head," who was kept advised of the running of trains by the nearest station master, usually broke the line directly a train had passed; as much of the meter-gauge as it was considered possible to relay before the next one was likely to arrive was at once dismantled, the ballast having been previously opened out and roughly leveled, the spikes and fish bolts loosened; meter-gauge rails unlinked at every fourth joint were merely pitched to either side so as to be clear of the new sleepers, while sleepers and small fastenings were thrown out clear of formation level. As fast as the metre-gauge material was removed, steel sleepers were laid down, spaced, and lined true to the lugs by knotted cords. A gang of men followed, forcing the 75-pound rails to their seats and linking them, and behind them came others doing the same with the 40-pound rails. As soon as a pair of 75-pound rails were laid in the seats and linked in, chalk marks were made along each rail to show the exact position of the sleepers, which were then adjusted by pinch bars, and fixed by driving the steel keys under the lugs. Finally, the keys for the meter-gauge rails were driven in, and the line roughly lifted and packed ready for the next train. There was a good reason for laying the 75-pound or outside rails first. To get a rail to drop into its ten seats, all the sleepers had to be simultaneously held up by pinch bars to one level, and to be at the same time in one line; and this was easily done with the 75-pound or

outside rails by the aid of a simple contrivance made of round iron five-eighths inch diameter, somewhat similar to the handle of an ordinary bucket, the ends of which clawed the sides of the sleeper, while the middle served as a fulcrum for the crowbar used to force the rail down. When the 75-pound rails were seated there was no difficulty whatever in getting the 40-pound rails into place, but the reverse was by no means the case. The amount of laying which could be done in a working day depended entirely upon the running of trains, but the average progress was about one-half mile per day. On two or three occasions 1½ miles were laid in one day at one "rail head." Three hours was usually the longest period during which the track could remain broken. The cost of laying the mixed gauge, including the removal of the old rails, but exclusive of carriage and distribution of material and finished topping of the line, was about 11 cents per yard, while the cost including all charges was 25¼ cents per yard.

BENGAL AND NORTHWESTERN RAILWAY (gauge, 3 feet 3⅜ inches).—On this road are used some of the improved cast-iron plate ties designed by Mr. George E. Moore, deputy consulting engineer of railways, and these have been favorably reported upon by Mr. Izat, the chief engineer. The tie is described further on. The Tirhoot section (formerly the Tirhoot Railway) is laid with Denham-Olpherts and Denham cast-iron plate ties, and also with sal and deodar timber ties. On other sections wooden ties of sal, pynkado, and creosoted pine are used.

BENGAL PROVINCIAL RAILWAY (gauge, 2 feet 6 inches).—This is a light railway between Tarkessur and Magra, on the East Indian Railway, and is intended for local traffic. It is laid with 30-pound T-rails on steel ties, contracts for which were placed in February, 1893. The ties are spaced 2 feet 9 inches apart, center to center, and are bedded in 6 inches of fine ballast under the ties. The railway (or steam tramway) is 30¼ miles long. The engines weigh 10½ tons, and have a rigid wheel base of 3 feet 6 inches, while the tenders weigh 5 tons. The cars are carried on four-wheel trucks or "bogies."

BEZWADA EXTENSION RAILWAY (gauge, 5 feet 6 inches).—This is a new line, 112½ miles long, running through an open and fairly level country, mainly composed of black cotton soil. It is single track with 66¼-pound steel T-rails on the Rendel or "pea-pod" steel ties. This line includes the Bezwada-Godaveri section of the East Coast Railway, 91 miles, laid with 75-pound T-rails on steel and wooden ties, in ballast of stone, sand, gravel, and moorum.

BHAVNAGAR, GONDAL, JUNAGARH AND PORBANDAR RAILWAY* (gauge, 3 feet 3⅜ inches).—The Dhoraji-Porbandar section, 69¼ miles long, has been laid with 41¼-pound steel T-rails on steel ties. Creosoted pine is used on the other sections.

BINA-GUNA RAILWAY (gauge, 5 feet 6 inches).—Work was commenced on this line, 73½ miles long, in 1892. The track is of 75-pound steel rails on steel ties. The line is worked by the Indian Midland Railway.

BOMBAY, BARODA, AND CENTRAL INDIA RAILWAY* (gauge, 5 feet 6 inches).—The following statement was sent me in June, 1894, by Mr. H. J. B. Hargrave, chief engineer:

> On our main line from Colaba to Wudhwan a continuous length of 165½ miles of road north of Broach has been laid on iron bowl or pot sleepers. They are also laid

on a length of 17 miles south of Broach, but there they are intermixed with wooden sleepers and are on different sections. Points and crossings are invariably laid on wooden (creosoted pine or teak) sleepers. The life of the creosoted pine sleepers would seem to be about eight years, and of the cast-iron pots about fifteen years. For my own part I prefer the timber cross-sleeper road. It is much softer to work over and in case of derailment there is not so much damage done as on the cast-iron pot road. The whole thing hinges on the price of pine sleepers, which at present cost 2, 3, and 5 rupees each (45 cents to $1.12). At this rate one road is as cheap as the other to maintain, and the initial cost is less for the wood. As to steel cross sleepers our experience is only just commencing. We have about 100 miles laid with them on the Godhra-Rutlam Railway, but can not say how long they will last.

BURMA STATE RAILWAY * (gauge, 3 feet 3⅜ inches).—In my former report it was stated that steel ties had been experimented with, and since then it has been stated in some of the engineering papers that in 1891 the Prome line was relaid and the Indian pattern of steel tie subtituted for the wooden ties, except at switches and frogs. Mr. Charles A. Bull, engineer in chief, wrote me, however, in April, 1894, to the effect that the railways in Burma are entirely laid with wooden ties, and that there is at present no talk of introducing metal ties, timber being very abundant. The Government report for 1893 gives the track as of 40, 41¼, and 50 pound rails on ties of pynkado wood, while teak, pynkado, ingyin, and theya are used on the Mu Valley line, which is independent of the Mu Valley Railway.

DELHI, UMBALLA AND KALKA RAILWAY * (gauge, 5 feet 6 inches).—This railway is 162 miles long, and the track is laid with Denham-Olpherts cast-iron plate ties, as used on the East Indian Railway, with 1,936 ties per mile, or 11 ties to a rail length of 30 feet. The rails are of double-headed section, weighing 75 pounds per yard. I am indebted to Mr. William Duff Bruce, consulting engineer, for statements of the cost of material and completed track, and, also, for a statement of the cost of maintenance of such track, prepared by Mr. Denham, one of the inventors of these ties, the latter statement being given further on.

Materials and cost per mile of single track.

	Number.	Tons.	Price.	Total cost.
Rails, 75 pounds per yard		117.86	$20.94	$2,467.98
Splice plates (10 per cent for 23-foot rails)	*360	7.40	26.25	194.25
Splice bolts and nuts	2,160	1.84	61.75	113.62
Ties (2 plates to each)	1,936	188.41	17.25	3.250.07
Tie bars	1,936	19.85	30.00	595.50
Keys and cotters, each	3,872	3.44	67.25	231.54
Total material		338.80		6,852.96
Freight and insurance to India		338.80	5.60	1,897.28
Cost delivered				8,750.24
Carriage to Delhi or Umballa		338.80	6.16	2,087.00
Carriage to site of works (40 miles haul)		338.80	.01	135.52
Loading and unloading			0.166	56.24
Tracklaying				293.33
Total cost per mile of track complete				11,322.33

* Pairs.

East Coast Railway (gauge, 5 feet 6 inches).—This is a new railway which will extend from Bezwada to near Cuttack, about 500 miles, and will eventually form a coast route between Madras and Calcutta, about 600 miles. (*See* Bezwada Extension Railway.) The report of the director-general of railways for the year ending March 31, 1893, stated that there are no great engineering difficulties to be encountered, and that the track would be of 75-pound T-rails, having about 300 miles on steel ties and 200 miles on wooden ties. In January, 1893, it was stated by the Indian papers that when the consulting engineer (to the Government of India) for state railways was inspecting the works he expressed the opinion that the ties on those sections of the line that bordered the coast should be of wood and not of steel, as the latter were likely to corrode and render the expenses in the end more heavy than those of wood. About half a mile of the track near the Cocanada coast was laid with steel ties, but (so it was said) they were condemned by the engineer in chief, while the Government was also said to have ordered that creosoted pine ties should be laid on all parts of the line near the coast.

In April, 1894, I received from Mr. James R. Bell, engineer in chief, the following letter, which is of particular interest as giving reliable information on the important question of corrosion of steel ties:

> This line does not as yet afford any reliable statistical information on the vexed question of the durability of metal sleepers. We have now about 320 miles of track, about half of which is laid with 135-pound Rendel steel sleepers dipped hot in tar. Between swamps, lagoons, irrigation "tanks" (i. e., large shallow embanked reservoirs), and paddy fields, and affected by two monsoons, two-thirds of the line is in an amphibious condition for nine months in the year, and it is generally recognized that the introduction of any thin metal sleepers here could only be justified by an urgency that left no time to procure timber. The sloppy "black-cotton" soil embankments engulf enormous quantities of ballast, and the road stands on a clay-like compost, like dough when wet and like rock when dry, so that sharp-edged sleepers with small bearing areas are particularly unsuitable to this environment.
>
> I suspect that the sleepers said to have corroded did so while still stacked on the sea beaches where they were landed, for I know as yet of no actual failures of sleepers under traffic, and indeed our first 100 miles have only been opened fourteen months and the rest a bare eight months. The gauge of the line is 5 feet 6 inches; rails, 75-pound Vignole (or T); 11 ties to 30 yards. The ballast, where of stone, shingle, or sand, is good; but moorum (a kind of clay conglomerate) is wholly bad. The traffic is as yet very light, not over 4 trains a day on an average. The engines weigh 90 tons with 8-wheeled tenders, and their heaviest axle load purports to be 16.35 tons, but is probably more. From experience elsewhere, we lay all salty lengths with timber sleepers, and expect that cast-iron "plates" (not pots or domes) will be better than troughs, but not so good as wood until after the earth walls are entirely consolidated.

East Indian Railway* (gauge, 5 feet 6 inches).—This road, as noted in my original report, has adopted as its standard the Denham-Olpherts type of cast-iron plate ties (*see* Pl. 23), and with successful results. According to a statement furnished in April, 1894, by Mr. F. E. Robertson, chief engineer, the number of ties then in use and the average annual percentage of their renewals for the last five years were as follows:

Ties.	Number.	Per cent of annual renewals.
Denham-Olpherts ties	2,483,609	0.64
Other cast-iron ties	240,369	2.74
Sal-wood ties	1,279,245	5.98
Other wooden ties (principally deodar)	1,044,958	5.28
Total	5,048,181	....

In regard to the track on wooden ties, it is of the English type, with double-headed rails secured in cast-iron chairs by wooden keys, but Mr. Robertson says that the latter are not suitable for a hot climate: "The round spike used with the chair is a poor job, and the road mostly stays where it is from force of habit, not because the spikes hold it tight. The Denham-Olpherts, our present standard tie, holds the rail well."

In August, 1892, Mr. J. W. Jones, assistant engineer, wrote me that the vulcanizing treatment for wooden ties had been proposed by him, but not tried. All the wooden ties imported from Europe were creosoted, but in many cases the sap did not appear to have been properly exhausted before the preservative was applied. About twenty-five years ago this company and some others started to creosote Indian fir (deodar), but gave it up, and in 1892 the wooden ties supplied in the country or imported from Burmah, Australia, etc., were not subjected to any preservative process. One reason for this was that the ties were destroyed by crushing long before they were likely to decay, owing to badly designed chairs with small base area; but now that chairs with broad bases are used the ties give better service, and a preservative process that would harden the wood would prove economical. Fir ties had not been imported for some years, but a lot were sent out in 1891. The wooden ties are of sal from Nepal and deodar from the Himalayas. Asna has been tried and condemned. When Mr. Jones wrote the company was making 500 complete Denham-Olpherts cast-iron plate ties daily at the Jamalpur works, using native iron. The track is of 75-pound double-headed rails, 30 feet long, with deep splice-bars 26 inches long secured by six 1-inch bolts, but the new splice-bars are 22 inches long, with four bolts. In 1893 an 85-pound bullhead rail was adopted for the divisions having the heaviest traffic. The ballast is of ¾ to 2½ inch broken stone, used liberally. With mixed ties there were 10 to 75 per cent of iron ties, and the iron rails were being replaced with steel at the rate of 80 to 100 miles per year. On December 31, 1891, the rails and ties were as follows:

	Miles.
Steel rails on Denham-Olpherts iron ties	798
Steel rails on wood or mixed wood and iron ties	423
Iron rails on Denham-Olpherts iron ties	89
Iron rails on wood or mixed wood and iron ties	679
Total	1,989

THE NALHATI RAILROAD* (4 feet gauge), 27½ miles long, had 2 miles laid with Denham-Olpherts ties with Molesworth's wedges (*see* Pl. 21 of original report). The railway now forms the Azimganj branch of the East Indian Railway, and in 1892 was widened to the 5 feet 6 inches gauge and laid with 82-pound iron rails on Denham-Olpherts cast-iron plate ties, with laterite ballast. The Gya branch was being relaid with Denham-Olpherts cast-iron plate ties in the first half of 1894.

EASTERN BENGAL STATE RAILWAY* (gauge, 5 feet 6 inches and 3 feet 3⅜ inches).—On this road the cast-iron plate ties are extensively used, and I am indebted to Mr. J. A. Anderson, M. Inst. C. E., engineer-in-chief, for a detailed statement furnished in April, 1894. There are 304 miles of standard Indian gauge (5 feet 6 inches) main line, and 587 inches of meter gauge.

Standard Gauge.—The track is laid throughout with double-headed iron and steel rails, weighing from 69 to 75 pounds per yard, and the rails now used for all renewals are of steel, 30 feet long, weighing 73 pounds per yard. The ballast is almost entirely of broken brick, but there are some short lengths of sand ballast under pot ties. There are 126 miles laid on Denham-Olpherts cast-iron plate ties, 21 miles on cast-iron pot ties, and the remaining 157 miles are on wooden ties, principally sal (*Shorea robusta*). There are a good many ties of different Indian, Burmese, and Australian woods also in the track on trial, but the local sal wood is as good as, and cheaper than, any other. It is a heavy, compact, tough, strong, and durable wood, weighing about 60 pounds per cubic foot. The wooden ties are 10 feet long, 10 by 5 inches section, and last from fifteen to nineteen years in the track, requiring about 6 per cent of annual renewals. There are 10 to 11 ties to a rail length of 30 feet, and the ties carry two 29-pound cast-iron chairs, each fixed by the iron spikes or fang bolts, the rails being secured in the chairs by teak keys on the outside.

The Denham-Olpherts cast-iron plate ties weigh 229 pounds each, made up as follows: 2 cast-iron plates, 176.1 pounds; 2 movable cast-iron jaws, 26 pounds; 1 tiebar ½ by 2 inches section, 23.1 pounds; 2 pairs of gibs and cotters, 3.8 pounds. The plates have each one fixed jaw, which with the movable jaw grips the rail just under the upper head (Pl. 23 of original report), so avoiding all injury to the lower head, and allowing for reversal of the rail. These ties make a very satisfactory track, practically as smooth as with wooden ties; they give little trouble for maintenance, and are easily replaced in case of accident, while their yearly renewals come to only 0.06 per cent—in fact, their life seems to be only limited by that of the tiebar. They are superseding both cast-iron pots and wooden ties on this line. They are spaced 11 to a 30-foot rail. Comparing the sal ties (with an average life of seventeen years) with the Denham-Olpherts ties (average life, sixty-eight years) it is stated that it would pay well in money value alone to use the iron ties, even if twice the price of the wooden ties;

but the actual proportion is about 7 to 4, while the additional cost and damage to track of changing the ties three times is avoided. Pot ties have not been quite satisfactory here, and have done best in sand ballast. The two cast-iron pots weigh 169 pounds; the tiebar, gibs, and cotters, 25 pounds; total, 194 pounds.

Meter Gauge.—On the meter gauge lines all the rails are of flange or T-section, the old ones 24 feet long and 40 or 41¼ pounds per yard for iron or steel, respectively. The steel rails now used for all renewals are 30 feet long and weigh 50 pounds per yard. The ballast is of broken brick, broken brick and stone, broken stone, and gravel, while in places where the ordinary soil is sandy, the wooden ties are merely boxed up with earth.

Of the total 587 miles, 24 are laid with the Rendel or "pea pod" steel trough ties, most of them being of the improved type with 2 clips punched up at each end, between which the rail is fixed by a long taper key, driven between one clip and the rail flange (Pls. 22 and 24 of original report). These are not quite satisfactory, the clips being weak and allowing the keys to get loose. They weigh 70 pounds each, and are spaced 11 to 12 to a 30-foot rail. There are 9 miles laid with different experimental cast and wrought-iron ties, 9 miles more with Denham-Olpherts plate ties, and the remaining 545 miles with wooden ties 6 feet long and 8 by 4½ inches section. These ties are mostly of sal, as on the standard gauge, and all the remarks made on the standard gauge apply also to the meter gauge ties. Each rail is fixed to the tie by two dogspikes.

The following table gives some particulars of the traffic:

	5 feet 6 inches gauge.	3 feet 3⅜ inches gauge.
Engine and tender in working order..........tons..	43. 6 to 61. 25	28. 25 to 34. 36
Heaviest load on driving axle..........do....	14. 08	8
Maximum schedule speed between stations..........miles per hour..	33. 4	23. 4
Average weight of passenger trains..........tons..	211	135
Average weight of freight trains..........do..	324	189
Train miles run in the year 1892–'93..........	1, 997, 299	1, 450, 789

GAEKWAR'S MEHSANA RAILWAY* (gauge, 3 feet 3⅜ inches).—The track is of 41¼-pound steel rails, with 52½ miles of steel ties and 40¼ miles of deodar ties.

GAEKWAR'S PETLAD RAILWAY* (gauge, 5 feet 6 inches).—This line, opened in 1890, is 13¼ miles long, laid with 66¼-pound steel T-rails on steel ties. It is worked and maintained by the Bombay, Baroda, and Central India Railway Company.

GODHRA-RUTLAM RAILWAY* (gauge, 5 feet 6 inches).—This is a new line, 115 miles long, through difficult country, the greater part of its length being on a grade of 0.5 per cent. It is laid with 75-pound T-rails, on steel trough ties, except for 35 miles on the Rutlam section, where deodar ties are used. In June, 1894, however, Mr. Hargrave, chief engineer of the Bombay, Baroda, and Central India Railway, reported that 100 miles of this line were laid with steel ties.

Great Indian Peninsular Railway* (gauge, 5 feet 6 inches).—This railway has 462 miles of double track, 824 miles of single track, and 244 miles of side track, or 1,992 miles of single track in main line and sidings. It is laid throughout with double-headed rails; 588 miles of iron rails, 50 to 85 pounds per yard, and 1,404 miles of steel rails, 69 to 86 pounds per yard. There are 1,632 miles of cast-iron pot ties and 360 miles of wooden ties 10 feet long and 10 by 5 inches section, as shown in the table:

Wooden ties:		
Teak		487,859
Creosoted pine		101,609
Miscellaneous		39,810
Total		629,278
Total miles		360
Cast-iron ties:		
Round pots	pairs..	454,162
Oval, old pattern	do...	934,637
Oval, new pattern	do...	557,087
Oval, R. and L	do...	899,800
Total pairs	do...	2,845,686
Total miles		1,632

For the following detailed statement as to the ties used and the experience with them I am indebted to Mr. A. J. Garret, acting secretary, the statement having been made in June, 1894 :

The weight of a single pot varies from 81 pounds (round) and 91 pounds (old oval) to 101 pounds, the latter being for our latest and best pattern, the R. and L., which means "right and left," permitting the keys on both rails to be driven in the same direction. This pattern has no cells to receive wooden rest pieces, but the rail bears on two cast-iron seats, one on either side of the chair and situated 13 inches apart, center to center, thus giving the rail a good bearing. Both the "old" and "new" pattern pots are too light, and the metal in them is not distributed to the best advantage. They have cells to hold rest pieces or cushions of elm, oak, hornbeam, etc., creosoted or otherwise prepared, and our experience is that when rails (especially those made of steel) are allowed to rest on them for any considerable length of time the chemical substance so corrodes and pits the bearing surface as to prohibit the turning of the rails. The round pots, our earliest pattern, are strong and permit of easy adjustment to level, but they do not afford the superior rail support that the oval pots do. A sleeper formed of right and left pots with cast-iron seats is composed and weighs as follows:

	Pounds.
2 pots, 101 pounds each, cast iron	202
1 tiebar, ½ by 2 inches, wrought iron	25.75
2 cotters, wrought iron	1
2 gibs, wrought iron	.41
Total weight of tie	229.16

We import no other pattern but this. It makes an excellent road and the breakages are very few. We are steadily working to eliminate all wooden sleepers from the road, and never relay with any but the R. and L. pots, unless forced to do so with the object of reducing expenditure in any half year, when we use the cheap creosoted pine All sleepers are spaced 3 feet apart, center to center. Points and crossings are laid on square-sawed teak sleepers, 10 by 5 inches, and of varying lengths to suit the spread of roads. Our renewals of sleepers per annum have been as follows:

	Wood.	Iron.
	Per cent.	*Per cent.*
Average, 1873 to 1892	4.57	0.80
Average for 1893	6.14	.57

The increase in renewals of wooden ties is due to our rejecting sleepers before their life had ended rather than lay new rails on them. Our renewals are carried on in continuous lengths and we make the road as thoroughly good as it can be made, in order to avoid any call for early disturbance of it. In other words, the increase may be put down as the result of our improvement policy. The decrease in iron-sleeper renewals is due to the gradual increase of the stronger type and to the use of better ballast. In the old days dirty ballast which caked in the pots caused great destruction of the weak oval pots. About 75 per cent of our ballast is either trap stone broken to cubes of about 1 inch sides or screen river shingle. The rest is of granitic sand or other inferior qualities which we are rapidly discarding. We are unable to state the difference between the cost of maintaining the road on wooden and iron sleepers, but in respect to labor it is about the same.

Passenger engines of the eight-wheel type weigh 42 tons, with 28 tons on the driving wheels and a wheel base of 8 feet. The six-wheel (all coupled) freight engines weigh 38½ tons on a wheel base of 14 feet 6 inches; and the eight-wheeled (all coupled) tank engines for the Ghat incline weigh 55½ tons on a wheel base of 15 feet 7 inches. The six-wheel tenders for passenger and freight engines weigh 28 tons on a wheel base of 11 feet. Long freight cars on four-wheel trucks weigh 35 tons, loaded, on a wheel base of 26 feet; and small four-wheel freight cars weigh 18 tons, loaded, on a wheelbase of 10 feet 6 inches. The regular speeds between stations are 17 miles per hour for freight trains, 22 miles for mixed trains, 27 miles for passenger trains, and 32 miles for mail trains. The traffic for 1893 amounted to 10,737,413 passengers and 2,831,869 tons of freight. During the year ending March 31, 1894, the southeast line between Poonah and Raichor was strengthened by the addition of an eighth tie to each rail length of 24 feet.

INDIAN MIDLAND RAILWAY* (gauge, 5 feet 6 inches).—The oval cast-iron pot ties, which are the standard ties of this road (p. 233 and Pl. 23 of original report), are giving very satisfactory results, and Mr. J. M. Wrench, chief engineer, writing in April, 1894, stated that he could speak most confidently of them. As to their life he could give no opinion, as his experience with them extends only over the last five years, since the railway was opened, but they appear to be as sound now as on the day on which they were laid. There is practically no corrosion or cracking; the efficiency of the rail fastenings is perfect; the noise is not great if the felt packing or cushion is used, and when once the track has settled together the amount of tamping for maintenance is not much. The track is a little hard. The pots weigh 80 pounds each and the rails 80 pounds per yard. These ties compare most favorably with the steel trough ties on the Bhopal State Railway (which is worked by the Indian Midland Railway), which, Mr. Wrench says, are now being renewed after an average life of nine years, their section being weak, so that they fail by cracking just below the rail. On the branch from Cawnpore to Kalpi there are 75-pound rails on Denham-Olpherts plate ties. The wooden ties on the line are practically worn out, and they are now being removed as rapidly as possible, after an average life of fourteen years, the 80-pound bowls being used in renewals. The frogs, switches, and crossovers are laid with wooden ties. The railway has 315½ miles of main line, from Bhopal to Agra, and three branches aggregating 361¾ miles, making 667¼ miles in all, while the Bhopal State Railway, from Itarsi to Bhopal, has 57.11 miles of main line and no branches.

Indian State Railways.*—In my original report was given a table of the numbers of metal ties sent out from England from 1874 to September, 1889, and I am indebted to the director-general of stores for the following statement of steel and iron ties sent to India, or under provision by the India Office, London, from September, 1889, to March 20, 1894. They are all for the 5 feet 6 inches gauge, no metal ties for the meter gauge having been sent out since 1889. The miles are calculated at the rate of 2,000 ties per mile:

	Miles of single track.
Steel cross-ties (number, 1,232,590)	616.25
Denham-Olpherts cast-iron plate ties (pairs, 120,250)	60.13
Total, 1889 to 1894	676.38
Total, 1874 to 1889	2,018.75
Total, 1874 to 1894	2,695.13

The sizes and weights of the Rendel steel ties for the two gauges are as follows:

Gauge.	Length of plate.	Width of plate.	Weight.	Weight of two keys.	Weight per mile.
	Ft. in.	*Inches.*	*Pounds.*	*Pounds.*	*Pounds.*
5 feet 6 inches	8 9	13½	120	2	214,704
3 feet 3⅜ inches	5 9	12	69	1.25	123,648

Jammu and Kashmir Railway* (gauge, 5 feet 6 inches).—This line, which was opened in 1890, is 16 miles long, laid with 75-pound T-rails on deodar ties, except where there are sags in the road to pass surface floods, in which places steel ties are used (*see* Queensland). The ballast is of stone, and there are about 1,900 ties to the mile.

Jetalsar-Rajkot Railway (gauge, 3 feet 3⅜ inches).—This railway, 46¼ miles long, completed in 1893, is laid with 41¼-pound steel T-rails, partly on steel and partly on creosoted pine ties.

JODHPORE-BICKANEER RAILWAY* (gauge 3 feet 3⅜ inches).—This line (formerly the Jodhpore Railway) has now 300 miles of track ot 36-pound steel rails on steel ties, and 64 miles of similar rails on jungle-wood ties.

KOLHAPUR RAILWAY* (gauge, 3 feet 3⅜ inches).—This railway was opened in 1891 and is 29 miles long, laid with 41¼-pound steel rails on steel ties.

MADRAS RAILWAY* (gauge, 5 feet 6 inches).—This is another of the roads which has adopted cast-iron pot or bowl ties. In April, 1894, Mr. H. R. P. Carter, chief engineer, furnished the following particulars: The length of line (exclusive of sidings, 132.256 miles) is 839.225 miles, of which 42.5 miles are double track, and the entire length, with the exception of bridges and culverts, is laid with the cast-iron bowl ties, the weight of which has been increased from 84 to 112 pounds each. The percentage of breakages for the past three years had been 0.58 per cent. No other description of metal ties are used, and frogs and switches are laid with wooden ties (either teak, jungle wood, or "sal," *Shorea robusta*). The ballast is of decomposed gneiss and sand. The average age of ties on December 31, 1893, was 22.87 years for the iron, 16.42 for teak, 5.72 for jungle wood, and 7.60 for creosoted pine. The rails weigh 65.75 and 84 pounds per yard, but the 75-pound rails are principally used. The amount of traffic in the six months ending December 31, 1894, was 4,714,986 passengers, 431,318 tons of freight, and 156,162 parcels.

In March, 1894, Mr. Julian Byrne, secretary of the company, stated that the company owned and operated 839¼ miles of line (42½ miles double track, 796¾ miles single track, and 130¼ miles of side track), nearly all of which is laid with cast-iron bowls. The section of rail was changed in 1893 to a 76-pound bullhead section, and there are ten pairs of bowls to a rail length of 30 feet. Mr. Byrne gives the following statement of weight and cost:

Metal ties, Madras Railway.

	Design of 1890.	Design of 1893.
Weight of one pair of bowls ....pounds..	200	224
Weight of one wrought-iron tie bar ....do..	31.5	31.5
Weight of one pair of gibs and cotters ....do..	1.62	1.62
Cost of bowls, tie bars, gibs, and cotters per ton, delivered at Madras	*$24.00	†$22.00
Cost of one pair of bowls delivered at Madras, including tie bars, gibs, and cotters, but excluding the cost of wooden keys, which are furnished in Madras...	*2.50	†2.52½

* In 1891. † In 1893.

MU VALLEY RAILWAY (gauge, 3 feet 3⅜ inches).—This line was authorized in 1891, and will be 156 miles long, laid with 41¼-pound steel T-rails on wooden ties. One of the Indian papers, in 1892, referred to the introduction of iron ties, stating that while the broken stone ballast answered well with the wooden ties it was not found to be so satisfactory with the metal ties. This railway is in Burma, and, as already stated, Mr. Bull, chief engineer of the Burma State Railways, reports that no metal ties have yet been tried.

MUSHKAF-BOLAN RAILWAY (gauge, 5 feet 6 inches).—This is a new line, 65 miles long, built as a loop on the frontier railway line to Quetta, in Beloochistan, to avoid the danger of communication being cut off by the landslides, which have caused so much trouble and expense in the "Mud Gorge" on the Sind-Pishin line of the Northwestern Railway. The line is mainly for military purposes, in connection with the protection of the northern frontier. The line starts at Sibi, 430 feet above sea level, and its summit is 5,900 feet above sea level. The maximum grade is 1.8 per cent, except on the upper section, where it is 4 per cent. The track is of 75-pound steel T-rails on steel ties of the State Railways pattern, but on the steep grades (which are "bunched" so that traffic can be worked over them by auxiliary engines) steel T-rails weighing 100 pounds per yard are used. The Railway Administration Report for 1893–'94 states that from Sibi to Abigum, 37 miles, the existing track material will be used—75-pound steel doublel headed rails for Denham-Olpherts cast-iron plate ties and 75-pound stee-T-rails on the steel trough ties. The 100-pound rails are laid from Abigum to Kolpur, 23 miles.

MYSORE GOLDFIELDS RAILWAY (gauge, 5 feet 6 inches).—This line is ten miles long, built in 1893, and is laid with second-hand double-headed 75-pound rails from the Madras Railway, carried on new cast-iron pot ties of the Greaves pattern. The maximum grade is 1.5 per cent, and the sharpest curve of 1,685 feet radius.

NIZAM'S GUARANTEED STATE RAILWAY (gauge, 5 feet 6 inches).—In March, 1893, the report of the director-general of railways showed 268 miles of steel ties (as against 109¾ miles in March, 1888), 62 miles with cast-iron bowls, and 2¼ miles of wooden ties.

NORTHWESTERN RAILWAY* (gauge, 5 feet 6 inches).—The use of steel ties continues to be favorably considered, and they have been used on several extensions opened since my former report. The additional mileage has not been reported, but includes the 36 miles of the Kundian and Mari branch on the Sind-Sagar frontier (military) line, where 75-pound steel T-rails are laid on steel ties, as also on the Quetta line. Mr. W. H. Cole, in a paper presented to the Institution of Civil Engineers in 1894, stated that nearly the whole of the Sind-Sagar line (300 miles) was laid in 1886 with steel ties in sand ballast, with a stone or brick topping. The soil, of sand and clay, is more or less impregnated with saline matter. The air is generally dry, but that portion of the line westward between the Salt range and the right bank of the Jhelum River toward the Indus is for months exposed to inundation, and is saturated by drainage from the hills. On this section marked ties which weighed 148 pounds in 1886 were found to weigh only 87 pounds in 1890, a loss of 61 pounds in four years. At the beginning of 1893, it was determined that wooden ties should be substituted when renewals became necessary, and, guided by the results of experiments with steel ties buried in sand on the East Coast Railway, it has been decided not to use steel ties within ten miles of the seacoast.

In November, 1894, I received the following statement (dated October 12) from Mr. G. H. List, M. Inst. C. E., chief engineer, whose delay in answering a request for information made early in the year was due to floods and other troubles having left him without the necessary time:

> My experience is that wood and cast-iron pots make the best roads, cheapest to lay, and easiest and cheapest to maintain and ride over. Steel-trough sleepers have not been an unqualified success on this road, owing to the presence of large quantities of saline matter in the soil. Where they are laid in clean, dry sand, or gravel ballast on a dry bank, and with no salt present, they answer admirably, but that state of matters is the exception with us, and I doubt if we will have over 300 miles of these sleepers left in ten years time. The pot or bowl sleeper on sand or fine gravel is the quietest running road; after that steel trough sleepers, and, lastly, wood or stone or brick ballast. The excessive noisiness of wood is due to the long dry weather we have, which bakes a bank hard and makes it sound like a drum. Most of our wooden-sleeper road has a flat-footed or T rail, with metal tie-plate and dog spikes, as in America, and it gives us no trouble. Some of such road is laid with chairs, spikes, and wood keys, as in England, and I am bound to say this is the easiest riding-road we have. The bowl sleeper also has a wooden key, and the steel-trough sleeper a steel key, or cotter. We have no trouble with fastenings. The Denham-Olpherts is a "suspended" road, with no key.
>
> I can not give you any details about the tamping of the different classes, as no special observations have been made, but we average 2½ to 3 men per mile, according to amount of traffic, for all classes of ties. Nor have we kept detail figures of the variation in cost of maintenance for each class of road (or track), as they are so terribly mixed up on each division; but it averages Rs. 250 ($84) per mile per annum for wooden and bowl sleepers, half as much more for Denham-Olpherts cast-iron plate sleepers, and twice as much for steel troughs. This last figure, however, is due to the special causes mentioned, namely, corrosion from salt. Given dry and favorable conditions, the cost for steel troughs should be less than that for wood, or equal to it. We have no points and crossings on metal sleepers of any class, but all are on wood. In fact, all station yards have wood sleepers, as shunting (or switching) derailments are frequent where native pointsmen (or switchmen) are employed, and metal sleepers will not stand the racket of it.
>
> So far as my experience goes on this line (nine years), metal has not displaced wood for ties, and will not do so as long as we can get local wood at a cost not exceeding 3 to 4 shillings (75 cents to $1) per sleeper and while silver exchange remains at its present figure. But if metal sleepers are ever greatly extended, then on this line the preference will be for cast iron, which makes a good, smooth-running road, fit for any speed. A road with bowls 100 pounds each and rails weighing 75 pounds per yard is easily laid and maintained, and the life of a sleeper is thirty years, at least, against fifteen years for wood, while the scrap is worth Rs. 50 ($16.66) per ton even if we do not recast it into bowls.

The following table, furnished by Mr. List, gives the miles of track of main line, exclusive of sidings, laid with the different kinds of sleepers, together with the average price per mile:

		Classes of ties.				Total.
		Deodar wood.	D.-O. plates.	Steel troughs.	Pots or bowls.	
		Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*
1. Miles laid on December 31, 1893		1,333½	48½	855½	345½	2,583
2. Miles of steel sleepers condemned to be renewed with wood during 1894		1,379½	48½	809½	345½	2,583
3. Average price per mile of each class of sleepers	rupees	6,250	14,638	11,961	10,612	....
	dollars	2,083	3,879	3,987	3,537	....
4. Average price per mile of fastenings	rupees	1,500	3,069	....	4,002	....
	dollars	500	1,023	....	1,334	....
5. Average price per mile of each class of sleepers with fastenings	rupees	8,000	17,000	12,000	15,000	....
	dollars	2,667	5,667	4,000	5,000	....
6. Average age	years	9.5	6.75	7	19.17	....

Oudh and Rohilkund Railway* (gauge, 5 feet 6 inches).—On this road there are various systems of metal track in use, as shown by the following statement of the mileage on December 31, 1893, as furnished by the general manager, Col. Brackenbury, R. E., and the chief engineer, Mr. F. T. G. Walton:

	Miles.
1. Cast-iron oval bowls	406.81
2. Wrought-iron saddleback bearers	61.98
3. Steel bowls	206.70
4. Steel trough ties	34.95
5. Wooden ties	30.67
Total	741.11

(1) These may be taken as the present standard type of metal ties in use on this railway, and it is hoped that a reliable pattern has now been obtained, the rail being secured by a steel key. The weight of one pair of bowls, with tie bar, is 223 pounds. The old pattern, in which the rail is secured by clips and bolts, weighs 184 pounds per pair. These have not lasted more than 20 years, and now break readily under the increased loads brought upon them.

(2) These have been condemned, as they are too light, weighing 105 pounds per pair.

(3) These have been condemned, as they bend and spread the gauge under the present loads. The weight of one pair is 95 pounds.

(4) These had been recently laid on a new branch.

(5) The wooden ties had been recently laid on a new branch and in other places to replace old cast-iron oval bowl ties.

As all the metal ties so far have been laid only in sand ballast, while all wooden ties are laid in kunkur ballast, no reliable records are available to show the respective cost of maintenance between iron and wood. There is, however, considered to be no reason to believe that such difference would be appreciable as far as the labor employed is concerned, the average number of men and cost of labor per mile being 2.81 men per day and $52.80 per annum.

The Lucknow-Rae-Bareli line and the Bareilly-Rampur-Moradabad lines, 152 and 56 miles long, will have 75-pound steel T-rails on steel and deodar ties. The 48 miles between Lucknow and Rae Bareli were laid with steel ties in 1892.

PONDICHERRY (gauge, 3 feet 3⅜ inches).—When the Gingee River bridge was rebuilt in 1885–'86, it was laid with 50-pound steel rails on cast-iron bowls. On other parts of the line wooden ties are used. The bridge is about 1,050 feet long, with seven spans of 150 feet each.

SOUTH INDIAN RAILWAY* (gauge 3 feet 3⅜ inches).—I am indebted to Sir Douglas Fox, the consulting engineer, for the following statement furnished by Mr. H. W. Notman, the secretary of the company, dated March 29, 1894. The first item includes 69 miles laid with wooden ties, on which, however, renewals were then being made with the pots. The system comprised 1,097 miles, including the 54 miles from Mayaveram to Mutupet, with track laid as follows:

	Miles.
Cast-iron pot ties	638.5
Steel cross-ties	348
Cast-iron Denham-Olpherts plate-ties	47
Wooden ties	63.5
Total	1,097

According to a writer in "Indian Engineering," this road, when originally built on the broad gauge of 5 feet 6 inches (being then the Great Southern of India Railway), was considered the cheapest line ever constructed in India. The cost was stated in my original report at $33,500 per mile. Sand ballast was available along the whole line, and Sir George B. Bruce, the consulting engineer, wisely adopted the plan of using the cast-iron pot ties that had been found so successful with sand ballast on the Egyptian railways.

> They served their purpose usefully and economically, and a steadier and better permanent way we have seldom traveled over in this country. But difficulties appear to have arisen since, and the same ailment that was expected to affect the East Coast Railway metal sleepers, has now arisen on the South Indian Railway. We may point out that there are certain districts traversed by this road where clean stone ballast would be an expensive remedy for a simple evil.

According to a statement from Mr. Logan, the chief engineer, sent to me in November, 1894, by Mr. T. H. LeMesurier, agent of the company, the length of the railway at the end of June, 1894, was 1,041.51 miles, and the following lengths of track with metal ties were in the main line at the end of December, 1888, and June, 1894:

	December, 1888.	June, 1894.
	Miles.	*Miles.*
1. Cast-iron pot sleepers, 80 pounds each, for 68-pound double-headed rails	121.73	115.56
2. Cast-iron pot sleepers, 70 pounds each, for 50-pound bull-headed rails	169.99	417.96
3. Cast-iron pot sleepers, 57 pounds each, for 41-pound flange rails	6.36	5.10
4. Transverse steel sleepers, 70 pounds each, for 41-pound flange rails	5.80	332.36
5. Denham-Olpherts cast-iron plate sleepers, for 41-pound flange rails	....	45.03
Total metal track ....miles	303.88	916.01

1. The reduction in mileage of these heavier cast-iron ties is due to the length on the main line between Tanjore and Trichinopoly being taken out in the renewals with material for 50-pound rails. The ties thus released were relaid on the Negapatam branch in place of decayed pine ties. This type of track has now been in service for twenty-seven and three-fourths years and has not shown any signs of decay or deterioration.

2. The increase in mileage of the medium-weight cast-iron ties is due to renewals of the track with wooden ties on the main line. This type of metal track was introduced in 1886, and is now the standard type, and will be used in all future renewals. The heavy renewals of these ties during the past half year, as shown in the following table, were probably due to slightly defective ties having been laid.

3. The reduction in mileage is due to renewals with material of type No. 2 for 50-pound rails. These light cast-iron ties for 41-pound flange, or T rails were laid in 1885, at the same time that the first consignment of steel ties was received. These pots have not shown signs of decay, but the renewals of the past five years compare unfavorably with the renewals of the other type of pot sleepers, which was no doubt due to the section of the lighter ties being rather weak.

4. The increase in mileage of track laid with the steel ties is due to the opening for traffic of the Villupuram-Dharmavaram section and the Nellore branch (formerly the Cuddapah-Nellore State Railway). The length laid on the old South Indian Railway main line was removed in 1889 for reasons given below. These transverse steel ties have lugs riveted on to form chairs, and an examination of them in 1887 led to the discovery that many of those laid in the station yard at Trichinopoly junction were completely punched through under the wrought-iron lugs forming the chair. In some cases the ties were rusted right through, while in others, which were not rusted so much, the lugs were punched through, or cracks had formed in the ties under the rail. The condition of the ties on the main line was nothing like so serious, yet many ties were found defective, being cracked under the lugs, or rail seats, the ties laid on curves being generally cracked round the lugs of the inner rail. The Trichinopoly junction yard is ballasted with laterite, and this, with lack of drainage, was unfavorable to the life of the tie. All the ties were removed from this yard and from the main track, and are now being used on sidings where better drainage can be given. A portion of the Nellore branch, above referred to, is laid with the Rendel steel ties of the Indian State Railway pattern. This section was opened for traffic in September, 1887; and in June, 1893, two of the ties were found very much corroded, having given way under the rail seat and being eaten through with rust, so that they had lost 25 pounds in weight. The embankment from which these were removed is ballasted with stone, but there was a considerable mixture of clay and gravel in the bedding. A further examination was made, with the result that ten ties were found in very bad condition, having lost from 10 to 22

pounds in weight. Since then the renewals have been increasing, as shown below. The Villupuram-Dharmavaram section is also laid with steel ties of the State Railway pattern, these ties having been laid in March, 1891. At Chittoor station, during the inspection of August, 1893, it was observed that the ties were beginning to show signs of corrosion. The station yard was ballasted with sand. The lugs on the ties of this pattern are inclined to open under traffic, and the keys become slack. The track is not noisy under trains if it is well ballasted and the ties are covered. All switches and crossings are laid on teak ties.

5.—The Denham-Olpherts cast-iron plate tie is laid on a portion of the Nellore branch. The renewals are high, owing, probably, to the tie being of a weak section.

The following table shows the record of semiannual renewals, being the percentages of the numbers of ties of each type in the track:

Renewals of metal ties, South Indian Railway.

Renewals for half years ending in—	Cast-iron pot ties.			Steel. ties.*	Cast-iron plate ties.
	Type No. 1.	Type No. 2.	Type No. 3.	Type No. 4.	Type No. 5.
December, 1889	0.012	0.053	1.090	....	0.243
June, 1890	.036	.025	.396	....	.612
December, 1890	.008	.003	.040	....	.750
June, 1891	.010	.005	.173	....	.420
December, 1891	.014	.019	.102	....	.207
June, 1892	.029	.009	.071	....	.301
December, 1892	.017	.001	.055	....	.207
June, 1893	.035	.009	.158	.004	.251
December, 1893	.012	.002	.112	.017	.174
June, 1894	.024	.007	.206	.130	.369

* Nellore branch only.

SOUTHERN MAHRATTA RAILWAY* (gauge, 3 feet 3⅜ inches).—In June, 1891, at a meeting of the company in London, the president stated that all the pine ties had been renewed with steel, except on the Mysore Railway, where creosoted pine and teak are used, and, as the renewals had to be made with teak ties, they had to wait for supplies from the Mysore forests. The number of pine ties then remaining was 150,000, and it was estimated that, judging from past progress, it would take three years to complete their entire renewal. On the Guntakal and Mysore frontier line, 119½ miles, opened to Dharmavaram in 1892 and to Hindupur, on the frontier, in 1893, the track is of 41¼-pound T-rails on the Rendel or "pea pod" steel ties. During the year ending March 31, 1894, heavy renewals of ties were carried out on six miles between Belgaum and Sulebhavi, the teak ties being replaced by steel; also on the Salpa and Alandi ghats, where the Australian karri wood ties laid in 1886 were so far deteriorated by excessive moisture that they had to be replaced.

TIES.

Denham-Olpherts ties.—The following statement of the cost of maintenance of track with cast iron and with wooden ties was compiled from actual results. The cost of the track with wooden ties was taken from accounts for 17½ miles. The figures as to the metal ties were taken from a line 205 miles long, laid with the Denham-Olpherts ties; 50¼ miles of this were double track, giving really 255¼ miles of track, the only wooden ties on which were the few at frogs and switches. The traffic is heavy. The freight engines weigh 71 tons (including tender) and have 15 tons on the driving wheels. They haul trains of 1,000 tons each (consisting of 62 cars, brake van or caboose, and an officers' car), the average weight upon each pair of freight-car wheels being 9 tons. For the statement I am indebted to Mr. Denham, as noted in the paragraph on the Delhi, Umballa and Kalka Railway.

Comparative cost for maintenance per mile of single track with Denham-Olpherts cast-iron plate ties and with wooden ties.

[From a statement prepared by Mr. Denham.]

WITH WOODEN TIES.

	Durability.	Renewals.
	Years.	*Per cent.*
Ties, sal (the best Indian wood)	12	8.330
Chairs (75-pound double-head rails)	346	.289
Spikes	340	.294
Keys	14¼	7.013

WITH DENHAM-OLPHERTS IRON TIES.

Plates (cast iron)	50.5	1.98
Jaws (cast iron)	62.5	1.60
Tie bars (wrought iron)	No limit.	....
Keys (wrought iron)	210.9	.474
Cotters (wrought iron)	490.1	.204

Cost of maintenance per mile per year for 17½ years.

WITH WOODEN TIES.

Ties	$311.35
Chairs	2.39
Spikes	.13
Keys	3.13
Total	317.00
Deduct for old material returned to store	26.38
Net cost	290.62

WITH DENHAM-OLPHERTS IRON TIES.

Renewals per mile per year	$34.06
Deduct for old material returned to store	16.12
Net cost	17.94

DENHAM-OLPHERTS IRON TIES.

In favor of iron ties per mile per year		$272.68
Saving in handling less quantity of ballast		20.00
Total saving in favor of iron ties, maintenance		292.68
Original cost of track with wooden ties, per mile	$4,976	
Original cost of track with metal ties, per mile	4,484	
Saving in favor of metal track		492.00
Cost of ballast for wooden ties, per mile	2,739	
Cost of ballast for metal ties, per mile	2,301	
Saving in favor of metal track		438.00
Total saving in favor of first cost of metal track, per mile.		930.00

Moore's ties.—The cast-iron plate ties invented by Mr. George E. Moore, deputy consulting engineer for railways, and tried on the Bengal and Northwestern Railway, are similar to the Denham-Olpherts ties in general principle, but the rails are set lower and the flat tie bar higher, the ends of the latter butting against the rail. Each tie consists of two plates 2 feet 10 inches long and 12 inches wide, weighing 82 pounds each; a wrought-iron tie bar five-eighths by 2 inches, weighing 24¼ pounds, and two cotters, weighing 2 pounds each. The weight of one tie complete is 192¼ pounds, and with 1,936 ties to the mile the weight of ties per mile of track is 166 tons. The change of gauge on curves is effected by turning the tie bar upside down, the lugs then bearing against the flange giving a gauge of 5 feet 6¼ inches.

Wooden ties.—The following notes show the general practice in regard to wooden ties, and none of the roads mentioned below use any metal ties:

Assam-Bengal Railway (gauge, 3 feet 3⅜ inches): Seven hundred and forty-two miles, to be laid with 50-pound rails on ties of sal, teak, pyngado and nagessur (or nahar).

Bengal Central Railway (gauge, 5 feet 6 inches): One hundred and twenty-five miles, 62-pound T-rails on creosoted pine ties, but sal ties are being used in renewals and on curves.

Bengal-Dooars Railway (gauge, 3 feet 3⅜ inches): Thirty-nine miles, 41½-pound steel T-rails on sal ties in stone ballast.

Cooch-Behar Railway (gauge, 2 feet 6 inches): Twenty-two and one-half miles, 25-pound steel T-rails on sal and ironwood ties in sand ballast.

Darjeeling-Himalayan Railway (gauge, 2 feet): Fifty-one miles, 40-pound rails on sal, oak, and chestnut ties, but sal only is used in renewals.

Hyderabad-Umarkot Railway (gauge, 5 feet 6 inches): Fifty-nine miles, 60-pound rails on deodar ties.

Mayarkram-Mutupet Railway (gauge, 3 feet 3⅜ inches): Fifty-five and three-fourths miles, to be laid with 40-pound iron T-rails on pynkado ties.

Nilgiri Railway (gauge, 3 feet 3⅜ inches): Sixteen and one-half miles, 40-pound steel T-rails and Abt rack rail on pynkado ties, laid on stone ballast, between dwarf walls 18 inches high.

Rajpora-Bhatinda Railway (gauge, 5 feet 6 inches): One hundred and eight miles, 68 and 75 pound rails on deodar ties.

Rohilkund and Kumaon Railway (gauge, 3 feet 3⅜ inches): Two hundred and twenty-one miles, 41½-pound steel rails on sal, teak, and deodar ties.

CEYLON.

CEYLON GOVERNMENT RAILWAYS* (gauge, 5 feet 6 inches).—In my former report it was stated that up to 1890 no metal ties were used, all the ties being of Baltic pine or native or Australian hardwoods. Since then, however, the advantages of metal ties have been recognized, as shown by the following extract from the report of Mr. W. T. Pearce, general manager, for the year 1892, at which time there were 191 miles of railway in operation:

> When in England, in 1887, I devoted considerable time and attention to the examination of the various metal sleepers in use and patented. I then satisfied myself that certain transverse steel sleepers would, under suitable circumstances, make a strong, reliable, and, in the end, cheap road, from the small attention which it would require to keep it in order, and the extra length of the life of the sleepers; these conditions also greatly reducing the responsibilities of the maintenance department. I did not, however, satisfy myself that metal sleepers would make such a satisfactory running road as wood, as the tendency of railway experts was to discourage their use so long as good timber ties were obtainable at a fair price, on the grounds that metal sleepers were apt to chatter. [This chattering does not occur with efficient fastenings.—E. E. R. T.] The scarcity and high price of good hardwood ties in Ceylon has, however, induced me to call upon the Crown agents to furnish the railway with a trial shipment of several of the most approved types of steel sleepers, which will be tested in various suitable sections of the railway line. I hope most sincerely that the trial will be a satisfactory one, and enable us to adopt the steel sleepers.

STRAITS SETTLEMENTS (FARTHER INDIA OR MALAY PENINSULA).

SUNGEI UJONG RAILWAY (gauge, 3 feet 3⅜ inches).—This railway is situated in the state of Sungei Ujong, and extends from Port Dickson, on the coast, to Seramban, 25 miles inland, the entire length being laid with steel ties of the Rendel type (Pl. 22 of original report). The line is owned by the Sungei Ujong Railway Company, and I am indebted to Mr. C. Maitland, the manager, for a statement dated April, 1894. The route is very tortuous, having many curves of 528 feet and 594 feet radius, with sharp reverse curves and a ruling grade of 1 in 80, or 1.25 per cent. The consulting engineers were Mr. William Shelford and Sir C. Hutton Gregory, both of London. The traffic consists of four to six mixed passenger and freight trains per day, hauled by engines weighing about 22½ tons, with wheel loads as follows:

	Pounds.
Leading wheels	15,176
Driving wheels	15,120
Trailing wheels	15,176
Truck or "bogie"	5,516
Total	50,988

The track was laid in 1889-1890, and consists of T-rails weighing 41¼ pounds per yard, carried on steel cross-ties, which ties were adopted on account of the destructiveness of the white ants and the alternations of very wet and very dry weather. The rails are laid with suspended joints, spliced by fish plates and angle bars 18 inches long, the former weighing 5¼ pounds and the latter 13 pounds each. Half of the line is ballasted with small mining sand, covered with heavier mining gravel, to prevent loss of the sand by heavy rains. The other half of the line is ballasted with a red clayey gravel of laterite nature, that with the least soil in it being chosen. This is not very good material, as it gets slightly muddy in wet weather, and pulverized during the dry weather. The sand is the better ballast, though it requires renewing frequently. The ballast is about 18 inches deep, loosely filled in at the center of the tie, and well tamped at each side of the rail seat, covering the top of the tie about 2 inches at the middle and sloping downward so as to leave a clear space below the rail and to leave the key attachments exposed. The ties are spaced as follows:

Length of rail.	Ties per rail.	From center to center of tie.	
Feet.	*Number.*	*Feet.*	*In.*
30	11	2	10
27	10	2	10
24	9	2	10
21	8	2	9
18	7	2	8

The ties are of trough section, 5 feet 6½ inches long over all, with the ends rounded down and corners flared out to a total width of 12¾ inches. In section the tie is 7¾ inches wide at the bottom, 4 inches wide at the rail seat, 4½ inches deep at the middle, and 4⅞ inches deep at the ends. The metal is three-sixteenths inch thick, except for the top table, 4 inches wide, which is three-eighths inch thick. Two lugs are stamped up out of the top table at each rail seat, and each rail is secured by a taper steel key 6 by ¾ by 1⅛ inches (split for 1¼ inches at the small end), driven between the rail flange and one of the lugs, the key being five-eighths inch thick at the side of and three-eighths inch thick above the rail. The ties weigh 63 pounds each, and the keys three-fourths pound each. On tangents and curves of over 1,650 feet radius (3½ degrees) both keys are driven on the outside of the rails, but on curves of less radius the key of the inner rail is driven on the inside of the rail. The ties were manufactured by the Tredegar Iron Company, of South Wales, and were treated with a varnish solution as a preservative against rust or corrosion.

The general results have been most satisfactory. During the first year the steel ties required more attention and more men per mile than wooden ties, but it is found after three years experience that the expenditure is almost a constant figure, and a further reduction of the staff is feasible. Tangents are slightly difficult to keep well in line. The keys seldom work out, though none of them have been opened out at the split ends, as they do not stand being opened and closed often when rails are renewed, etc. There is no trouble with maintenance, and after the ties have been well packed they require little attention, while owing to their grip on the ballast no creeping is noticed, and the closed ends prevent slewing or lateral motion on curves. There have been no derailments in three and a half years, and derailments only caused slight indentations of the ties run over by the wheels, making no alteration in the gauge. The best hardwood ties not treated by preservative processes do not last more than six years and cost about 50 cents each. In April, 1894, the steel ties were in as good condition as when they were laid, and there is no trouble from rust except at the wharves, where the spray from the waves occasionally wets them.

SUMATRA.*

The railways of this Dutch colony are owned by the home government, and, as noted in my former report, are laid with Post's steel ties imported from Holland. The ballast is of broken stone, gravel, and volcanic sand. The rails are of T-section, weighing 51½ pounds per yard, and being 4.4 inches high, 3.6 inches wide over the base, and 23 feet long. They are spliced by steel angle bars and attached to the ties by bolted clamps which admit of widening the gauge as much as 1 inch on the sharp curves. The ties are 6 feet 3 inches long, 4 inches wide on top at the rail seat and 9.5 inches wide over the bottom, and 3.4 inches deep at the rail. Those for the rack are 4.6 inches wide on top at the middle, but the others are 5.4 inches wide and 5 inches deep at the middle. Those for ordinary track are narrower and deeper at the middle than at the rail seats, but those for the rack rail divisions are of uniform section throughout to afford a seat for the chairs carrying the rack, which is of the Marsh (or Riggenbach) ladder type. The ordinary track weighs 211.3 pounds per yard, and native laborers can lay 3,280 to 4,920 feet per day of ten hours. The track with rack rail weighs 376.3 pounds per yard, and can be laid at the rate of 984 to 1,312 feet per day. Switches and turnouts are laid on steel ties.

In November, 1894, Mr. J. W. Yzerman, of Solok, Sumatra, furnished me with data regarding these lines. One hundred and ten and thirty-six one-hundredths miles were laid with steel rails in 1888–1891, Mr. A. Kuntze being the engineer in charge. Sharpest curves, 390 to 656 feet radius; steepest grades, 7 to 8 per cent on rack-rail sections and 1.2 to 3 per cent on adhesion sections. There is a heavy freight and passenger traffic. The heaviest engines weigh 57,750 pounds, with 42,200 pounds on the driving wheels. The steel rails weigh 86.4 and 87.2 pounds, and are spaced at 3.28 feet and 2.87 feet. They are of mild steel, plunged in a bath of hot coal tar. One hundred thousand ties were rolled at the Hoerde Works, and 121,000 pressed by the Gutehoffnung Works, costing 98.89 cents and 102.51 cents on the dock in Holland. The expense of maintenance is $130 per mile per annum, including cost of ballast.

JAVA.

The railways of this Dutch colony are under the direction of the Netherlands state railways, of Holland, through the colonial department of public works. They are of 3 feet 6 inches gauge, and it has been said that they are laid with Post's steel ties, similar to those used in Sumatra, but Mr. Yzerman, in describing the Sumatra railways, as noted above, says that no steel ties are used in Java.

CHINA.

PORT ARTHUR RAILWAY (gauge, 3 feet ⅜ inch).—This line has 4,220 of the Boyenval and Ponsard steel ties (*see* France), which were laid in 1889 for a length of 2 miles 2,160 feet. They are 6 feet long and weigh 70 pounds each, including the fastenings and base plates for 40-pound T-rails.

TONKIN.

HA-NOI TRAMWAYS (gauge, 2 feet and 3 feet 3⅜ inches).—On the Ha-Noi street railway 52 of the Boyenval and Ponsard steel ties (*see* France) were laid in 1893 for a length of 156 feet. They carry two tracks of 2 feet and 3 feet 3⅜ inches gauge, and weigh 57 pounds each.

JAPAN.

USUI RAILWAY (gauge, 3 feet 6 inches).—This railway has been built as a link between the northwest and southeast coast lines of railway, and is situated on the east slope of the central range of mountains which forms the backbone of the main island. The ascent is very difficult and the line has to rise 1,800 feet in five miles. The Abt rack rail system was therefore adopted, and the line was completed in the spring of 1893. The line is 7 miles long, with 26 tunnels, and the rack rail is laid for 5 miles, the grade being 6.66 per cent, with short pieces of level at the passing places. The track is of T-rails, secured by Post's clamps and T-headed bolts to Vautherin steel ties, spaced 2 feet 10⅝ inches center to center. The ties are 7 feet 2⅝ inches long and weigh 106.12 pounds each. The rails are spliced by angle bars and six bolts. The rack is composed of three bars supported in cast-iron chairs bolted to the ties.

SECTION 5.—SOUTH AMERICA, CENTRAL AMERICA, WEST INDIES, AND MEXICO.

GENERAL REMARKS.—In the countries included in this geographical division metal track is already extensively used, and its use is steadily increasing. Both cast iron and steel are used, but the former, while extensively adopted in the past, is not being used on roads making new experiments in this direction. In such cases steel cross-ties of trough section are generally selected. In certain districts where good timber is not obtainable it is being found economical to import the metal ties, thus obtaining a better and more permanent track. Railway construction in South America has been comparatively small during the past few years, owing to financial and political complications, but late in 1894 an order was placed with an English firm for steel ties for a plantation railway in South America, the locomotives and cars for which are to be built by firms in the United States. In Central America very little has been done. In the West Indies, however, there has been greater activity, and steel ties have been largely used on the new lines, both for ordinary and agricultural railways. In Mexico the Mexican Railway Company is steadily pursuing its policy of introducing steel ties in renewals.

ARGENTINE REPUBLIC.

GENERAL REMARKS.—In only one case has a special return been made in regard to the progress of the use of metal ties, and that shows an increase of 88 miles of track with cast-iron bowls.

Two railways, the names of which are not stated, are reported by Ponsard & Co., of Paris, to have laid some of the Boyenval and Ponsard steel cross-ties (*see* France). Both railways have a gauge of 4 feet 8½ inches. One line has 4,500 ties 7.54 feet long, weighing 93 pounds with fastenings and base plates for the T rails; these were laid in 1889 for a length of 2 miles, 1,000 feet. The other line has 8,037 ties, weighing 66 pounds each, which were laid in 1891 for a length of 4 miles, 3,111 feet.

These additions (which certainly can not be considered as representing the total extent of the progress of the use of metal ties) bring the totals up as follows:

Summary of metal track in the Argentine Republic.

	Cast-iron bowls.	Steel cross-ties.	Total metal track.
	Miles.	*Miles.*	*Miles.*
Total for 1894	3,438.15	200.21	3,638.36
Total for 1890	3,350.15	193.41	3,543.56

Central Argentine Railway* (gauge, 5 feet 6 inches).—In April, 1894, Sir Douglas Fox, the consulting engineer, informed me that this line had then a total length of 746 miles, of which 728 miles were laid with cast-iron pots and 18 miles with wooden ties.

BRAZIL.

General Remarks.—In June, 1894, Mr. Charles Neate, M. Inst. C.E., of London, reported to me upon four Brazilian railways for which he is consulting engineer. The Southern Brazilian Railway has had 23,000 Rendel steel ties (for 11.16 miles of track) sent out since 1889, and ties of the same type are to be sent to the Donna Theresa Christina Railway. On the Great Western of Brazil Railway and the Conde d' Eu Railway, which are situated well within the tropics, between the seventh and ninth degrees of south latitude, there has been less difficulty in procuring native hardwood ties at a reasonable cost, and such ties have an average life of about five years. All these railways were mentioned in my original report, and the latter had then about 20.46 miles of track laid with cast-iron bowls.

Summary of mileage of metal track in Brazil.

Railway.	Bowls.	Cross-ties.	Total, 1894.	Total, 1890.
	Miles.	*Miles.*	*Miles.*	*Miles.*
Central of Brazil	....	36	36	....
Conde d'Eu	20½	....	20½	20½
Donna Theresa Christina	....	2½	2½	2½
Minas and Rio	....	2½	2½	¾
Paulista	....	1	1	....
San Paulo	62	....	62	62
Southern Brazilian	....	11	11	¾
Total	82½	53	135½	86½

Central Railway of Brazil* (gauge, 5 feet 3 inches and 3 feet 3⅜ inches).—No returns have been received from the officers of this government railway (formerly the Dom Pedro Segundo Railway), but Mr. E. T. Gunning, general manager of the Minas and Rio Railway, stated in May, 1894, that steel ties have been very extensively used for some time past. These ties, I am informed by Ponsard & Co., of Paris, are of the Boyenval-Ponsard type (*see* France), and were laid in 1891 as follows: 38,000 ties, weighing 106 pounds each, on 21 miles, 3,120 feet, of broad gauge; and 25,000 ties, weighing 75 pounds each, on 14 miles, 1,500 feet, of narrow gauge. The revolution stopped the continuation of contracts, but these ties were also to be used for renewals and extensions. In 1892 the Government placed an order in Belgium for 40,000 steel ties.

Donna Theresa Christina Railway* (gauge, 3 feet 3⅜ inches).—My original report recorded about 2½ miles laid with the Howard and Rendel steel ties, and in June, 1894, Mr. Charles Neate, of London, the consulting engineer, wrote me that it is intended to send out some more ties of the Rendel pattern as soon as the economic condition of the railway permits. This pattern is considered to be more simple and efficient than any other. The cost of different ties, delivered, has been estimated as follows: Native wood, 20 cents; creosoted Baltic pine, $1.03; steel ties, $1.24.

MINAS AND RIO RAILWAY * (gauge, 3 feet 3⅜ inches).—In May, 1894, Mr. E. T. Gunning, general manager, wrote me that 1 kilometer (0.62 mile) was laid with steel ties under 50-pound rails during the first half of 1890. The length was too short to permit of special observations being taken as to wear, etc., but the general results have been so satisfactory that another section of 1.86 miles with 70-pound rails is about to be laid on the mountain division of the road, where the grade is about 3 per cent.

PAULISTA RAILWAY (gauge, 5 feet 3 inches and 3 feet 3⅜ inches).—Owing to the excellent results obtained on the Central Railway of Brazil, this company desired to try the Boyenval and Ponsard steel ties, and in 1893 laid 750 ties, weighing 106 pounds each, on 2,250 feet of broad gauge, and 750 ties, weighing 75 pounds each, on 2,250 feet of meter gauge.

SOUTHERN BRAZILIAN RIO GRANDE DO SUL RAILWAY * (gauge, 3 feet 3⅜ inches).—In June, 1894, Mr. Charles Neate, of London, the consulting engineer, stated that since his report, made to me in December, 1889, there have been sent out about 23,000 steel ties of the Rendel pattern used in India, representing some 11.16 miles of track. This is the only type used, no other form being considered so simple and efficient as this, and while there has not yet been sufficient experience to enable the life of the ties in Brazil to be determined, the experience in India points to the probability of their being very durable, and therefore economical. The present low price of steel greatly favors the use of steel ties.

In 1891, when the line was seven years old, it was stated that the heaviest maintenance expenses were for ties, which were already beginning to decay and to require renewal. The contract which was made in Brazil for ties could not be relied upon, and the company found it necessary to send out from England 30,000 creosoted pine ties and 4,000 steel ties, the former costing 86 cents each in England. The line has 4,000,000 ties, and in April, 1891, the president stated that the company must face an annual renewal of 30,000 to 50,000 ties. The later ties sent out were 6 feet 6 inches long instead of 6 feet, but cost the same price as given above. He further stated that a complete record of all ties was being kept, as to their location, date of laying, etc., so that information can be gathered later as to their life. The following is an extract from a statement made by the president of the company at a meeting in England in March, 1892:

> The quantity of sleepers which we have put into the line has been very largely increased. In point of fact, we put down more than twice as many sleepers as in

> the previous year. The directors have adhered to the policy of sending sleepers as much as possible from this country. There are a variety of reasons which have led them to adopt that course, one being the difficulty of obtaining reliable sleepers in the country itself. The Government has entered the market for sleepers as a competitor, and it is difficult in consequence to obtain the class of sleepers which we desire to have. A further reason is that creosoted pine sleepers are certainly very much more durable, and that steel sleepers are perhaps almost indestructible. We have, therefore, sent out large quantities of creosoted pine, and we have sent out quantities of steel sleepers. It is particularly at the curves of the line that the steel sleepers are being used, their greater rigidity and strength affording greater safety against accident.

At the annual meeting of the company in London, in May, 1894, the president stated that 15,000 steel ties had been sent out during the current year. These cost 4*s.* 6*d.* each ($1.10), delivered at Rio Grande, while creosoted pine ties sent out from England about the end of 1893 cost 3*s.* 1*d.* (75 cents) each. He also called attention to the astonishingly low price to which the price of steel ties had fallen.

VENEZUELA.

GENERAL REMARKS.—A railway between Puerto Cabello and San Felipe was commenced about 1865 but never finished, and on this line the Livesey cast-iron bowls were used. The Quebrada Land, Railway, and Mining Company's line, and the Barquesimeto Railway, running from the port of Tucacas to the Aroa mines and Barquesimeto, about 112 miles in all, are both laid with steel ties, and the former has been in operation for several years. The older types of metal track are not found to be satisfactory under modern conditions of service and traffic, but on the new railway from Caracas to Valencia, opened in 1894, the German contractors have used Krupp steel ties.

Summary of metal track in Venezuela.

Railway.	Wrought-iron and steel cross-ties.	
	1894.	1890.
	Miles.	*Miles.*
Barquesimeto (Southwestern)	54.56	....
Bolivar	47.25	55.00
Caracas and Venezuela	114.00	....
Puerto Cabello and Valencia	2.50	2.25
Total	218.31	57.25

BARQUESIMETO (SOUTHWESTERN OF VENEZUELA) RAILWAY (gauge, 2 feet).—The following report, dated May 23, 1894, has been received from Mr. A. D. Mitchell, acting agent, and Mr. A. J. Gonzalez, railway engineer, of the Quebrada Railway, Land, and Copper Company and the Southwestern of Venezuela (Barquesimeto) Railway Company, Limited:

> This line starts from a junction (El Hacha) at kilo. 75 (46½ miles) from the coast, on the Bolivar Railway, and reaches the town of Barquesimeto, a distance of 54.56

miles. At kilos 53 (32.86 miles) it attains a height of 2,300 feet above sea level, falling to an altitude at the terminus of 1,800 feet. The line was opened for public traffic in January, 1891. The maximum curve is 150 feet radius, and the maximum grade is 3¼ per cent.

It is laid throughout with 40-pound steel T-rails and Livesey steel sleepers of trough section with nearly vertical sides and having lugs stamped up and steel keys for rail fastenings, as in the Rendel ties (*see* pl. 22 of original report). The metal is three-sixteenths of an inch thick throughout and the tie weighs 48 pounds. It is 4 feet 8 inches long, 4 inches wide on top, 6 inches wide on the bottom at the middle, and 10 inches at the ends; 3¼ inches deep in the body, and 5 inches at the ends. In longitudinal section it is somewhat concave. The sleepers are not giving satisfactory results, although well shaped. Corrosion is setting in very rapidly and the fastening is very inefficient (quite the opposite experience from that with the Rendel ties in India, Mexico, etc.—E. E. R. T.). It consists of a tapered key with one edge grooved to fit the edge of the rail flange, and driven inside or outside between that and a little bracket or lug projecting from the sleeper. These keys and the bracket rust very rapidly, and the former falls out, allowing the rail to cant or tip outward. On the sharp curves the brackets or lugs are forced by the leverage of the rail into an upright position, and although they can be hammered back, the metal is weakened, and they very soon yield to the strain. The ballast used is very largely river gravel and sand. On the upper portions of the line broken schistose rock is used to some extent, but is not satisfactory. There are 9 sleepers to a 24-foot rail, the joint sleepers spaced 2 feet and the others 2 feet 9 inches center to center.

It may be said that none of the metal sleepers in use here have been found suitable. The iron sleeper is much too light, wants lateral grip in the ballast, and the fastening is insufficient. The Bolivar Railway steel sleeper is very difficult to pack with the available ballast, although most excellent as regards durability, fastening, and resistance to corrosion. The Barquisemeto (Southwestern) Railway sleeper is well-shaped, and with sand or fine gravel ballast is capable of being packed to fair line and level, but with other class of ballast it would be very difficult to pack. The metal in these sleepers seems most susceptible to corrosion, and the rail fastening is quite inadequate. A good sleeper for sand or fine gravel ballast could be had by combining the Livesey form of sleeper with the Kerr-Stuart fastening, and having it properly coated for protection against rust. Wooden sleepers are found to give by far the best results for keeping line and level and for easy running. Native hard-wood sleepers 5 feet by 8 inches by 4½ inches cost about 70 cents each, but the supply is very limited, and being used green their durability is very uncertain. My own opinion is that good creosoted timber imported is more likely to give good results than the native timber procurable. This agrees with the experience of English engineers in Brazil, India, and other tropical countries. The goods (freight) traffic up and down the line during the year 1893 amounted to 10,366 gross tons of 2,240 pounds.

BOLIVAR RAILWAY* (gauge, 2 feet).—This line, like the Barquisemeto Railway just mentioned, is owned by the Quebrada Railway, Land and Copper Company, and I am indebted to the same gentlemen for the following report made in May, 1894:

The railway extends from Tucacas to the Aroa copper mines and has a length of 55 miles, of which 53¼ miles are laid with 50-pound steel rails and 1¾ miles with 50-pound iron rails; the latter are worn out and will shortly be replaced by steel. The first construction, in 1874–1877, embraced about 44½ miles of 30-pound iron rails with fish plates and a small proportion of 28-pound iron rails with a shoe or chair joint and no fish bolts, while the remainder of the line was laid with 50-pound iron rails with the usual fish plate and bolt joints. From 1886 to 1889 the 28-pound and 30-pound rails were replaced by steel of 50 pounds, and since then the 50-pound iron rails have been gradually eliminated until there are now only 1½ miles, as above. The steel rails are mostly 21 feet long, with a few 18-foot rails to carry joints off bridge ends. The joint fastenings are plain fish plates 14 inches long, with 4 square-necked five-eighths inch bolts. These plates seem hardly strong enough, and angle plates would no doubt be an improvement, but can not be used on account of the limited space between the fish-bolt nut and the rail flange. The sleepers at present in the line are as follows:

	Miles.	
Mallett's patent wrought-iron buckled-plate sleepers	32.90	
Kerr, Stuart & Co.'s steel sleepers	14.35	
Total metal sleepers		47.25
Native hard-wood sleepers	5.65	
Creosoted pine sleepers, 5 feet by 8 inches by 4½ inches	2.10	
Total wooden sleepers		7.75
Total length of line		55.00

The wrought-iron sleepers are flat plates one-eighth inch thick, weighing 24 pounds each, dished or buckled in the middle to form a sort of trough of V-section, open at the top, leaving the ends and sides flat, and on the flat sides are the distance studs and the hook-headed fastening bolts, with nuts on the under side of the plate. The plates were 4 feet long and 9 inches wide, the dished portion being 3 feet 7 inches long, 5 inches wide, and 2½ inches deep at the middle. These were laid during the first construction of the line. The first specification allowed for 6 sleepers per 21-foot rail, but afterwards 8 were used. When the 30-pound rails were taken up and the road relaid with 50-pound steel rails, the iron plate sleepers were utilized by punching extra bolt holes to fit the wider base of the new rails. These weakened the sleepers very considerably at the bearing of the rail, and very many have cracked across through the holes. The dog-headed or hook-headed bolt has also given trouble to keep in place so as to hold the foot of the rail. There was a small washer provided, with edge cut and twisted up to prevent turning, but these washers soon became worn out by the jar of trains and allowed the bolt head to turn round off the rail. All these plate sleepers are quite worn out, and steps are being taken to replace them. The renewal will probably be with Georgia yellow pine or pitch pine, creosoted. Some creosoted pine sleepers (class not known), laid fifteen to seventeen years ago and recently examined, have given remarkably good results both in the road and on bridges.

It may be said about the buckle plate sleepers that for light traffic, with straight lines or curves of large radius they are useful, but being very shallow they have no grip in the ballast and are unstable laterally. In fact from kilos. 83 to the mines (3½ miles) they were not used, in view of the sharp curves on that section. They are easier to pack and keep to better level (surface) than the inverted trough type, but allow for no cant of the rail. Only 9½ miles of the iron sleepers are well ballasted with slag from the copper smelting furnaces, the balance being packed with roadside stuff, mostly ordinary soil, red earth, etc. The slag is mixed, as regards size, from 2 inches cube (sometimes larger) down to the size of coarse gravel. The sleepers packed with slag have worn out much more quickly than the others. The depth of slag below the sleeper varies from 4 to 8 inches.

The steel sleepers are of Kerr, Stuart & Co.'s pattern (*see* p. 72 and Pl. 4 of my original report.—E. E. R. T.). These were laid at different times between 1886 and 1889, and have proved very durable, corrosion up to the present time being very insignificant. They are of trough section, with flaring sides and narrow bottom flanges, and are bent lengthwise to give the rails an inward cant. They are 4 feet long, 5 inches wide on top, 7 inches within the bottom flanges and 8 inches over the bottom flanges, and about $2\frac{1}{4}$ inches deep. The ends are closed. The metal is three-sixteenths inch thick and the tie weighs 50 pounds. A riveted bracket or rail brace buts against the underside of the rail head on the outside, and on the inner side the rail flange is held by a clamp and bolt, with nut inside the tie, while a key driven between the bolthead and a rib on the clamp prevents the bolt from turning. The fastening has shown itself very effective and reliable, requiring almost no attention, and keeps the road well together in case of derailment, while the gauge is perfectly maintained. For the sharp curves of 120 to 300 feet radius on the mines section, special sleepers one-half inch wide in gauge are used. A repairing sleeper is also in use, with one outside bracket bolted to the top plate instead of being riveted as in the ordinary type. This enables the sleeper to be slipped in below the rails at the middle of a rail length. There are 8 sleepers to a 21-foot rail, the joint sleepers spaced 2 feet and the others 2 feet $8\frac{9}{16}$ inches center to center. The form of the sleeper is not satisfactory. It is most difficult to pack, and it is almost impossible to keep it to fair level (surface) in the ballast in use here. There are 8.68 miles of steel sleepers ballasted with the furnace slag, the balance being packed with roadside stuff. I am not aware of the cost of the iron sleepers, but the steel sleepers cost about $1.23 each in United States currency.

The traffic for the year 1893 was as follows, in gross tons of 2,240 pounds:

	Tons.
Crude ore and regulus to coast, and company's materials from coast to works and mines	31,356
Goods traffic, up and down	15,358
Total main line traffic	46,714
Mines to smelting works	57,085
Total traffic	103,799

The tonnage from mines to smelting works passes over the main line between kilos. 84 and 88.66 (3 miles). The Barquisemeto (Southwestern) Railway traffic up and down is included in the 15,358 tons passing over the Bolivar Railway.

Caracas and Valencia Railway (gauge, 3 feet 6 inches).—This railway (sometimes styled the Great Venezuelan Railway) was built by the Grosse Venezuelan Eisenbahn Gesellschaft, of Hamburg, and was opened in January, 1894. It is parallel with the coast but on the west side of the high and steep coast range. It connects the two towns named, from each of which there is a railway to the coast, one from Caracas to the port of La Guayra and the other from Valencia to the port of Puerto Cabello. The line is 114 miles long, though the direct distance is only about half that, the development being in order to keep the maximum grade down to 2 per cent. The minimum radius of curves is 262 feet, and there are numerous curves of 328 feet radius on the mountain division. From Caracas the line ascends to the summit at Los Teques, 4,021 feet above sea level, with a tunnel 900 feet long, the longest of the 86 tunnels on the line. The road then descends to the valley and encounters no great engineering difficulties.

The width of roadbed is 11 feet 6 inches on banks and 14 feet 9 inches in cuttings. The ballast is of gravel, broken stone, and coarse river sand, there being 12 inches of bottom and 6 inches of top ballast. The gauge of 3 feet 6 inches was probably adopted as being that of most of the other railways in Venezuela, built under the somewhat common misapprehension that a reduction in the gauge necessarily means a reduction in cost of construction, equipment, and operation. The track is laid with steel T-rails weighing 52.7 pounds per yard, which are carried on steel ties, nine to a rail length, the joint ties spaced 24 inches and the intermediate ties 32 inches center to center. The fastenings are said to be of a new and improved type, very substantial and easy to lay and replace. The locomotives are tank engines of English and German manufacture, weighing 35 tons in working order. The cars are of the American type and were built in Germany.

La Guayra and Caracas Railway (gauge, 3 feet).—The ties are of a wood known as "vera," a species of greenheart.

Puerto Cabello and Valencia Railway* (gauge, 3 feet 6 inches).—This line is 34 miles long, and in April, 1894, Mr. W. A. Smith, general manager, stated that it was laid throughout with native timber ties, 7 feet long and 8 by 5 inches section, except on the rack-rail incline of 8 per cent grade, 2½ miles long, which is laid with the steel ties referred to in my original report. They are of trough section, 6 feet long, 9½ inches wide at the middle, and spreading to 12 inches at the ends, and weigh about 80 pounds each. They have closed ends. There are two riveted clamps for each rail, each clamp secured by two rivets. The flange of the T-rail butts against the outer clamp, and a flat steel wedge, or key, with corrugated surface, is driven between the top of the inner rail flange and the clamp which projects over it. The chair for the three-bar Abt rack-rail is fastened to the middle of the tie by two bolts. Mr. Smith states that this incline has been worked for about six years, and the ties have given satisfaction, but he has ordered some new ties and is having them made rather heavier, as the present ties show a tendency to crack under the rails.

UNITED STATES OF COLOMBIA.

Cartagena and Magdalena Railway (gauge, 3 feet).—This is a new railway built by an American company to connect the seaport of Cartagena with the river port of Calamar, on the Magdalena River, which river is navigable for nearly 900 miles above that point. The line is 65 miles long. The maximum grade is 2.75 per cent, compensated for curvature. Mr. S. B. McConnico, the managing director, stated in June, 1894, that the track is laid with Belgian steel T-rails, weighing 45 pounds per yard. The ties are partly of Southern pitch pine from Alabama and partly native hard wood obtained in Colombia. Dimensions, 6 by 8 inches, 8 feet long. Cost, delivered, about 60 cents, gold. The first ties laid, being not yet two years old, there has been little opportunity to judge of their life, although it has already been found that certain of the native woods are rapidly decaying, while others give promise of long life. This emphasizes, of course, the great importance of carefully selecting the kinds of native woods to be used. So far the pitch-pine ties show no evidences of decay. The small white ant (called comejen) is very destructive to many kinds of wood, but the resinous quality of pitch pine seems to be something of a protection against them. White pine, oak and certain native Colombian woods are very quickly attacked and destroyed. Something less than a year ago the Haskins Wood Vulcanizing Company of New York sent down 100 of its vulcanized ties to be used as a test, and they have been put into the track for that purpose, but of course the period is yet too short for demonstrating results. The railway company has purchased 1,200 more of these ties, in order to make the test more complete. The bridges and pier are constructed of heavily creosoted Southern pine, under contract with J. W. Putnam, of New Orleans, who, until his recent death, leased the Louisville and Nashville Railway Company's creosoting works at Pascagoula, Miss. Most of the bridges are ordinary pile structures; some, however, being single and double deck framed. At the crossing of the Dique Canal, which is considered a navigable stream, a center-pivot swing bridge is constructed on a center pier of creosoted piles, having 60 feet clear span on each side for the passage of boats. This pivot span is of iron and is the only iron structure on the line. The approaches are of creosoted piling and aggregate about 800 feet in length.

WEST INDIES.

GENERAL REMARKS.—Metal track is being extensively used for ordinary and agricultural railways, and the careful and complete design of the track and track work of the Puerto Rico railways is specially worthy of note.

Summary of metal track in the West Indies.

	Steel cross-ties, miles.
Martinique	1.12
Puerto Rico	189.00
San Domingo	14.25
Total, 1894	204.37

CUBA.

MATANZAS RAILWAY (gauge, 4 feet 8½ inches).—In April, 1894, I was informed by the engineer that no metal ties are used, but various native woods, using the heartwood only. These ties have an average life of five years.

UNITED RAILWAYS OF HAVANA (gauges, 4 feet 8½ inches, and 2 feet 6 inches).—Mr. E. J. Balbin, engineer of track and works, wrote me in March, 1894, that no metal ties have been laid on this line, and that he did not think they had been tried on any railway in Cuba. This company has 276 miles of railway, 264¾ miles of standard gauge and 11¼ miles of narrow gauge. The track is laid with steel T-rails, weighing 60 to 65 pounds (4½ to 5 inches high) per yard for the former and 40 pounds per yard for the latter. The greater part of the line is ballasted with fine broken stone, and the rest with earth, but the latter is being replaced with broken stone. The ties are of native woods, 9 feet long and 6 by 8 inches or 7 by 7 inches (weighing 215 to 220 pounds) for the standard gauge; and 6 feet long, 5 by 5 inches section (weighing 65 to 70 pounds) for the narrow gauge. The average life of these ties is estimated at ten to twelve years.

JAMAICA.

Jamaica Railway (gauge, 4 feet 8½ inches).—On this line there are about 53,000 black cypress ties, 21,000 yellow pine ties, and the remainder creosoted pine ties. The ties are 6 by 8 inches and 8 feet long, spaced 2 feet center to center. Mr. Wellington, C. E., of New York, in his report upon the condition of this railway in 1893, stated that about 5 per cent of the uncreosoted ties had been taken out as being "rotten," whereas fully half of these were still good for one to three years' service, and he advised that such removals be stopped in the interest of proper economy.

MARTINIQUE.

Agricultural Railways (gauge, 3 feet 9 inches).—On the agricultural railways for the transport of sugar cane 2,000 Boyenval-Ponsard steel ties (*see* France) were laid in 1893 for a length of 1 mile 750 feet, replacing wooden ties. The ties weigh 55 pounds each. The planters are reported to find a considerable economy and greater length of life of these ties, which will insure further orders and the general use of steel ties.

PUERTO RICO.

Puerto Rico Railway (gauge, 3 feet 3⅜ inches).—In 1890 the Puerto Rico Railway Company, under a concession from the Spanish authorities, ordered 330,000 of the Boyenval-Ponsard steel ties (*see* France). These ties are 4.25 feet long and weigh 50 pounds each, with fastenings and base plates for 40-pound T-rails 32.8 feet long. The fastenings consist of two short screws or studs to each rail, with wide button-shaped heads fitting over the edge of the rail flange, the head having a square projection on top for the track wrench. These screws pass through holes in the riveted tie-plates or base plates, and are tapped into an iron filler plate or washer underneath the tie-plate in the open trough. The rails are laid with even joints, and there are 12 ties to a rail length of 32.8 feet and 9 to a rail length of 26.24 feet. In the former case they are spaced 20 inches center to center at the joints, then two spaces of 0.863 meter, and the remaining seven spaces of 0.864 meter, or, say, an average intermediate spacing of 34 inches. The spacing of the ties is marked with chalk on the web of the rail. The men handling the ties are furnished with leather shields for the hands. The ballast is 14 inches deep at the sides, 6.2 feet wide on top, and 11.48 feet on the bottom. It is nearly level with the top of the rail head outside, and between the tracks it is formed in a curve starting from the bottom of the web of each rail.

In the track instruction book, prepared by the Government engineers, Mr. C. Abrami and Mr. R. Le Brun, it is pointed out that the trackmen should not apply full force on the wrenches for the rail attachments, as the fastenings will be no tighter, while there is liability of damaging the threads. The frogs and split switches are carried on 10 steel ties 24 to 25½ inches apart, while tie No. 1 (at the rail joint in front of the switch) and the head-blocks Nos. 2 and 3, are 16 inches apart. The head blocks are 11 feet long, carrying the switchstand, and 4 ties 9 feet long carry the frog and guard rails. All the other ties of the turn-outs are ordinary ties. To insure accurate spacing of the switch ties in laying, flat iron bars or templates are used, having the edges notched to fit over the ties. The ties on each branch of the turn out are 34¼ inches apart. Both ordinary and three-throw switches are used, and the arrangement has been entirely satisfactory. On bridges the ties are bolted to the top chords of plate girders, the bolts passing through the bottom of the tie (*see* Pl. 6 of original report).

These ties were laid in 1890 on a length of 189 miles, and in April, 1894, Ponsard & Co., of Paris, wrote me that the Puerto Rico Railway Company has still 250 miles to construct, for which this firm will furnish the ties.

SAN DOMINGO.

CENTRAL DOMINICAN RAILWAY (gauge, 2 feet 6 inches).—In 1890 there were laid 25,000 of the Boyenval-Ponsard steel ties (*see* France), covering a length of 14 miles 1,500 feet. They weighed 66 pounds each. The makers report that the results have been very satisfactory and that the railway company will continue to use these ties in the completion of its line. In September, 1894, Mr. Edward Hall, chief engineer and general manager, wrote me as follows:

> The first 11 miles of this railway are laid with steel ties, and about 4 miles of this is on the Abt system of rack railway. This road has been in operation something over a year, and was constructed by a Belgian company. The extension now being constructed into the interior will be laid with ties of mahogany and other hard woods of the country, and also hard pine of the Southern States. As but little of the new line is in operation, I can not yet make a comparison between the metal and wooden ties. The metal ties will undoubtedly be very durable. I think, however, it will take more men per mile to keep the track in condition with the steel ties than with the wooden ones, but we have not enough of the wooden ties in use now to form a good comparison.

MEXICO.

GENERAL REMARKS.—The cast-iron pot ties first introduced are not very satisfactory under modern conditions of service, but the Mexican Railway finds such excellent results in economy and efficiency from the use of steel cross-ties that they have been extensively applied in renewals. These ties and fastenings are extremely simple, and have given equally satisfactory results in India and South America.

Summary of metal track in Mexico.

Railway.	Cast-iron bowls.	Steel cross-ties.	Total.
	Miles.	*Miles.*	*Miles.*
Interoceanic (1892)	35	15	50
Mexican (1893)	....	170	170
Total, 1894	35	185	220
Total, 1890	....	....	77

INTEROCEANIC RAILWAY OF MEXICO (gauge 3 feet).—About 50 miles of this line were laid with English cast iron pot ties of the Livesey pattern, but they are said not to have been satisfactory. According to a statement made by Mr. John Birkinbine before the Engineers' Club of Philadelphia in June, 1893, almost one-fourth of these have been replaced by steel ties, and further replacement is made as rapidly as finances permit. The steel ties now used are 6 feet long, weigh 90 pounds each, and have near the ends square bolt holes, but no clips. These nest nicely for shipping, and cost $1 (gold) per tie delivered at Vera Cruz. Wooden ties 8 feet by 6 inches by 6 inches cost in the vicinity of Pueblo and Mexico 63 cents for pine and 95 cents for oak; therefore, at the present exchange the pine ties cost in gold 42 cents and the oak ties 64 cents each. As railway supplies pay no duty, the expense for steel ties is therefore not greatly in excess of that for wooden ties.

MEXICAN RAILWAY* (gauge 4 feet 8½ inches).—The work of laying steel ties still continues, and up to the early part of 1893 they had been laid on about 150 miles of track, including the Pachuca branch. These ties are of the Rendel or Indian pattern, 8 feet 3 inches long, with lugs stamped up for the rail fastenings, and having the top table thicker than the sides (*see* Pl. 22 of original report). They weigh 124 pounds each, or 126 pounds with the two steel keys holding the rails. In 1893 orders were placed in England for 48,000 steel ties and 105,600 steel keys for the same, and arrangements were made for laying them on the whole distance of the mountain ascent from Paso del Macho to Boca del Monte, a distance of 60 miles.

The following extract from the report presented at a meeting of the company in November, 1893, shows very clearly the economy resulting from the use of the permanent steel ties:

> Above all, there were two subjects as to which we thought that a well-considered scheme, to be carried out more or less rapidly as circumstances would permit, was especially desirable. These two administrative matters of primary importance were the relaying of the whole line with steel sleepers, and the assuring ourselves that we possessed a stock of locomotives suited to modern requirements, of the best type, and in such a state of order that money shall not be wasted on useless repairs. It has been a subject of great satisfaction to the board that our long discussions have not been in vain, and we have arrived, both with regard to the reconstruction of the permanent way and also as to our stock of locomotives, at a decision which we have every reason to believe can take the shape of a scheme amply sufficient for our purposes and within the limits of our resources to carry out. We have already

provided steel sleepers at the rate of 2,000 a mile for a distance, from the coast in the direction of Mexico, of about a little more than 170 miles. This leaves us about 120 miles still to do. Now the cost of laying 120 miles with steel sleepers at the rate of 2,000 a mile, on the basis of present prices, would be £78,000 (United States value, $390,000). Hitherto the revenue has been contributing to the purchase of steel sleepers $6,000 a month. As steel sleepers have been provided on the part of the line where they are most necessary, and as we must economize where we can, we propose to reduce this contribution from revenue to $4,000 per month, or $48,000 a year, which, if we take the dollar at the rate of eight to the pound, is £6,000 ($30,000 United States) a year. But we found on examination that if we left off where we now are, and did not lay any more steel sleepers than we now have on the upper section of the line, the cost of providing wooden sleepers on the length we should thus have to deal with might be taken with sufficient accuracy for practical purposes at this same figure of £6,000 a year.

This is a charge, therefore, which must fall upon revenue, and no contributions from the amounts we have in reserve for improvement of the line can be so applied as to relieve revenue from the current yearly charges that properly fall on it. But if we put steel sleepers instead of wooden sleepers, and take seven years to carry out the process, we should at the end of the time have the line laid throughout with sleepers which require scarcely any renewal, so that at the end of seven years the £6,000 a year charged to revenue would disappear altogether out of the accounts. Steel sleepers, however, would cost a great deal more than the kind of wooden sleepers which we should be obliged to use, as no better are to be got, and this extra cost is a permanent improvement to the line which we may very properly take from our funds available for that purpose as an addition to what revenue is bound to contribute. We propose to add £5,000 ($25,000) a year for seven years out of our improvement fund to the £6,000 a year contributed by our revenue, and thus make a total of £11,000 ($55,000) a year, which, continued for seven years, gives a total of £77,000 ($385,000); that is the sum, as I have above stated, required to lay the whole line with steel sleepers on the scale of 2,000 to a mile. But there is a further improvement, on the great utility of which our advisers strongly insist, and with which revenue has nothing to do. This consists in the strengthening of the roadway by using 288 extra steel sleepers where we have only used, or propose to use, 2,000. I may mention that the advantage of using more than 2,000 sleepers to the mile is now so largely recognized that some of our neighbors, I believe, have no less than 2,600 to the mile, but our engineers, looking to the weight of our rails, are satisfied that with an amount very slightly falling below 2,300 a mile we shall have a roadway the excellence of which will never admit of any question. To provide these extra sleepers we shall have to spend about £20,000 ($100,000), and this amount we propose to take out of our improvement fund, so that when the whole scheme is carried out we shall, at the end of seven years, have spent £42,000 ($210,000) out of revenue and £55,000 ($275,000) out of our improvement fund. Then we shall have a line of 293 miles, including the Pueblo branch, of which 64 miles in the mountain district will be laid with specially heavy rails and sleepers, and with 229 miles laid with steel sleepers on the increased scale of which I have just spoken. And then we may hope that our expenditure on the permanent way or track will for a long length of years be so inconsiderable that it need not be taken into account.

MEXICAN INTERNATIONAL RAILWAY (gauge 4 feet 8½ inches).—In May, 1892, Mr. C. P. Huntington wrote me that he contemplated experimenting with several thousand metal ties, but that so far the prices had been a little too high. No later information has been furnished in response to inquiries.

MEXICAN SOUTHERN RAILWAY (gauge 3 feet).—On this line steel ties 8 feet long, weighing 110 pounds, are said to be in use.

SECTION 6.—NORTH AMERICA.

UNITED STATES.

GENERAL REMARKS.—Since the date of my former report some further experiments have been made with different forms of metal ties, but little practical progress has been noted, and it is to be regretted that difficulties connected with the necessity of insulating the rails from the ties (owing to the use of a rail circuit for signal operations) have delayed the putting in of the 18,000 steel ties manufactured for the New York Central Railway. While the natural slowness to adopt new systems and the increased first cost are largely responsible for this small progress, it is almost certain that another important reason is the economy which has been effected in the use of wooden ties by placing metal tie plates between the rail and tie (as described further on in this report), thus effecting economy and improving the track at very slight cost. Such methods, however, may be considered as merely postponing, and not preventing, the increased use of metal track in the future. The railroad commissioners of Connecticut, in their report for 1893, again referred to the probable economies to be derived from the use of metal ties, due to the reduced cost of maintenance, but they make no mention of the more immediate economies to be effected by the use of preservative processes and metal tie plates for wooden ties. Their remarks were as follows:

> It is now some sixteen years since experiments began in Europe and India in the use of metal ties, and their use has now become common on the Continent and nearly universal in India and Mexico. Very great improvement has been made in their construction, and though the Pennsylvania Railroad Company has, we believe, entirely abandoned their use after trial [this action has little or no significance, as shown later.—E. E. R. T.], we think it would be good management for our companies having the heaviest traffic to make trial of them. The first cost is, of course, greater than that of wooden ties, being three or four times the cost in this State, but European experiments have demonstrated that the life of the metallic tie is from four to five times that of wood, while the cost of repairs and maintenance of track where metal ties were used has been about 34 per cent less than where wood is used. Should trial show the same to be true in this State there would be no question as to the utility of the metal tie.

The commercial importance of the manufacture of steel ties as an industry is commented upon briefly in Part II ("Manufacture" and "Conclusions").

I have appended to this report a list of metal-track patents issued since my former report, and this list includes about 250 patents, making a total of 750 since 1839. The remarks made formerly upon such patents (p. 276 of original report) apply equally to the later ones, as a whole; for, while the number is considerable, the proportion of these with useful or practical ideas is very small. In fact, it is surprising and rather discouraging to note (1) how little originality there is in the designs; (2) the numerous modifications of existing designs for ties and fastenings; and (3) the hopeless complication and impracticability of many of the designs. As, however, the questions of invention and design are important, I have thought it well to include notes of various designs of ties which have been put forward beyond the "patent" stage, or have even, in some cases, been tried experimentally.

In regard to the ties of which a few have been made and put in service, and for which the inventors naturally make claims of "proved excellence" and "entire satisfaction," it may be as well to point out here that such trials have little or no practical value, since the adjacent wooden ties may (and generally do) relieve the metal ties of weight and strain. If the metal ties have open ends the wooden ties offer resistance to lateral motion, although the inventor of the former may claim that his "tests" prove that closed ends or other means to prevent lateral motion are unnecessary. The same is true in regard to the fastenings, as a system which gives good results when applied for a portion of a rail length may be an utter failure when it forms the sole fastening for a length of track. Similarly, from the expense of maintenance of a few metal ties the inventor may argue that he can show a great reduction in maintenance expenses by the use of his ties, sometimes even going into elaborate estimates to prove this and to prove the vast saving to be derived by the use of metal ties, whereas in point of fact it is probable that the adjacent wooden ties have sustained most of the service which is credited to the metal ties. As a matter of fact, then, no general deductions can be drawn from the results observed with a few ties. In saying this I do not wish to be understood as being inimical to such experiments and trials (for they are certainly a step in advance of designing ties on paper), but merely as wishing to present very strongly the fact that no conclusions of value can be based upon such limited trials. On the other hand, no metal track can be expected to give satisfactory results until it has been put in actual service and modified in accordance with the experience thus obtained, and it is safe to say that such experience will show that modifications are necessary in every case.

All railways are of the standard gauge of 4 feet 8½ inches.

Summary of metal track in the United States.

Railway.	Steel cross-ties.	
	Miles.	*Feet.*
Chicago and Western Indiana	....	1,000
Delaware, Lackawanna and Western	....	250
Long Island	....	950
New York Central and Hudson River*	10	1,320
Philadelphia and Reading	1	....
Minor experiments (estimated)	....	500
Total	11	4,020

* Only 1,320 feet are laid.

ATCHISON, TOPEKA AND SANTA FE RAILWAY.*—In my former report reference was made to the experimental use of about 22 of the Taylor ties on the Illinois Division (then the Chicago, Santa Fe and California Railway), and, as stated on authority from officers of the road, the results had not been satisfactory, there being considerable trouble in maintenance, the cost of which was much greater than with wooden ties. In May, 1894, inquiry made of the engineers resulted in the information that only one is left, and it is not known when the others were removed, as the division roadmaster and section foreman are dead, but it is thought that they were gradually replaced by wooden ties. Those in charge state that when the last two were in service the only way that track could be kept up was by having a good oak tie on each side. The ties seem, therefore, to have been entirely worthless. Each tie consisted of two trough-shaped supports, 14 inches long, 8 inches wide on top and 9 inches on the bottom, of three-eighth inch metal, and placed lengthwise of the rail. A vertical slot in each admitted the end of a tie bar five-eighths by 4 inches, with notches to fit over the sides of the trough. The inner edge of the rail was held by a lug as the support, and the outer end by a lug on the tie bar, an arrangement which allowed of no adjustment or tightening. (P. 287 and Pl. 30 of original report and note on the Columbian tie further on.)

CHATTANOOGA AND LOOKOUT MOUNTAIN RAILWAY.*—At the time of my former report it was understood that some of the Schofield steel ties were to be tried, but I am informed that none have ever been laid.

CHICAGO AND WESTERN INDIANA RAILWAY.*—On this road the Standard steel ties have been in service since October, 1889, and a statement from the roadmaster was given in my original report. This is a terminal road with very heavy main and suburban traffic, furnishing terminal facilities for six of the important railways entering Chicago, and using the Polk street terminal station. In January, 1891, Mr. J. W. Clarke, general roadmaster, wrote as follows to the Standard Metal Tie and Construction Company, of New York:

> Replying to your inquiry relative to the present condition of the Standard metal ties that are in our south-bound track, south of Sixty-ninth street, I would state that these ties have now been nearly fifteen months in use, in which time over 37,500 trains have passed over them. The cost of maintaining them has been so small as to be hardly worth taking into consideration, for the reason that it consisted of redressing the shoulder on the west side where teams along Wallace street occasionally drive too close to the track and tear away a portion of the shoulder, but the cost of redressing the ballast is not chargeable to the ties. Where this track, however, necessitated tamping, we found that about one-third of the time was consumed that would be required to tamp the same number of wooden ties. I think this is due to the fact that the bottom of the tie is nearer the surface, and consequently requires no digging and less power to raise the track sufficiently to allow the tamping to be done. The firmness with which the ends of the rails are held upon the foundation makes it impossible for them to move.
>
> The heads of the rails are perfectly even, and the usual "click, click," which the wheels make in passing over the ordinary joints on wooden ties has entirely disappeared, and the section, when riding over it, seems like one continuous rail. I find, also,

> that the ends of the rails on the wooden ties are slightly flattened, while on the steel ties the rail ends are perfectly smooth and even, which indicates the absence of the wheel blow at the joint, so injurious to rail and rolling stock. With the Standard tie I find that the rail continues to stand perfectly upright, and the wear is directly on top of the rail head, while with wooden ties the rails are slightly listed outward and the wear is mostly on the inside of the rail head.
>
> The sudden and sometimes severe climatic changes to which Chicago is subjected led me to expect that there would be considerable heaving of the tie when the ground became frozen, and sinking when the ground thawed again, and that shimming would be so difficult as to render the ties objectionable on that account; but there has been no heaving or settling whatever. The track has remained in perfect line and surface, and no shimming has been required.
>
> The broad fastening of the Standard ties, which holds the rail so firmly on its foundation, permits less rail deflection than with the wooden ties and spike fastenings, which, in my opinion, accounts for the smoothness and uniform elasticity of the track. There has been no loosening of the blocks by swelling or shrinkage, and the blocks recently examined were found to be in as good condition as when first inserted. There have been no loose bolts or nuts whatever; the rails are as firmly held now as when first laid. On the morning of the 15th instant, a truck under a loaded grain car broke down while passing over this piece of track. One tie was bent, but so slightly as to be hardly noticeable. There is every indication that the ties will remain in good condition and service for many years, and the saving in road-gang wages, and in their greater safety and smoothness in riding which they make, should merit their favorable consideration.

Later in the same year (1891) Mr. Clarke made a statement of the experience with these ties, showing that he found the total expense on 1,000 feet of track laid with steel ties, during nineteen months, was $45.50. The greatest part of this was expended in the first surfacing up in soft ballast to bring the steel ties to the same elevation as the wooden ties in the opposite track. During the same nineteen months the cost of labor alone on the 1,000 feet of track alongside laid with wooden ties was $210.25. The saving in labor alone would therefore have been sufficient to purchase 65 new steel ties. The track was exposed to a very heavy traffic, but Mr. Clarke stated that the part laid with the Standard tie was "not only safe, smooth, and pleasant to ride upon, but the ties were a money-saving device, and should commend themselves to railway men from that standpoint." He added that by reason of the rail being held rigidly upright, the life of the rail was increased very considerably. He also observed that there was less oscillation and vibration in the engines and cars passing over them, especially in heavily loaded cars of yielding material like grain. He believed, also, that rolling stock would have a longer life for these reasons.

DELAWARE AND HUDSON RAILWAY.*—Steel cross-ties of the "Standard" pattern were laid for about three-fourths of a mile, near Saratoga Springs, N. Y., in 1890. They weighed 90 pounds each, had creosoted bearing blocks for the rails, and were spaced 2.6 feet apart. These ties were described and illustrated in my former report. They were found, however, to be somewhat unsatisfactory and were taken out after a year's service. It is stated, however, by Mr. Swift, the chief engineer, that their failure here may have been due to the soft nature of the roadbed where they were tried. The ballast is of fine gravel, and exceedingly bad frosts have to be contended with, so that the conditions were admitted to be severe, and the ties might have worked well in better ballast and a more equable climate. (No such trouble, however, has been met with on the Chicago and Western Indiana Railway, where they have been in use since 1889.) There was also found to be a lack of sufficient bearing surface. The fastenings of the rails to the ties proved excellent, and there was no relaxing of these fastenings and no cutting of the creosoted bearing blocks. The Standard Steel Tie Company states that trouble was experienced by the flowing of the ballast from the ends of the tie, the ballast being filled in to the rail base and then sloped down, so that the vibration under passing trains caused it to flow. This would easily be remedied by filling the ballast in against the rail and shouldering it out level for some distance beyond the ends of the ties. This road has since been conducting experiments with sections of track laid with ties of different woods, treated by different preservative processes, and protected by different styles of metal tie-plates.

DELAWARE, LACKAWANNA AND WESTERN RAILWAY.*—About 100 of the Morrell steel trough ties (see Pl. No. 32) have been in use for the past two years on the Morris and Essex division, and Mr. A. Reasoner, superintendent, stated in July, 1894, that they give very good satisfaction, "as good, in fact, as I could expect." The ties are in use at West End, and Summit, N. J., and Scranton, Pa. The ties are of trough or channel section, placed with the open end upward, and resemble the standard steel ties (Pl. No. 30, of original report) except in the fastenings and in some other particulars noted further on. They weigh 100 pounds and cost about $2 each. The tie is 8 feet long over the bottom, 7 inches wide, and 3 inches deep. The rails rest upon wooden blocks and are secured by clamps with a vertical bolt on each tide of each block. The bolt has a hook-shaped head, and can therefore be removed and replaced without disturbing the tie.

DENVER AND RIO GRANDE RAILWAY.—Some ten years ago the trial of Krupp steel ties from Germany was proposed, and it was estimated that ties weighing 60 pounds each would cost $1.53 each, delivered at Galveston, Tex., duty paid.

INTERNATIONAL AND GREAT NORTHERN RAILWAY.—Some of the Saunders ties were laid at Austin, Tex., in 1891, and Mr. L. L. Thomas, the roadmaster, wrote in May, 1892, that after twelve months' service they were giving satisfaction and had not been touched since they were laid. These ties are described farther on.

LAKE SHORE AND MICHIGAN SOUTHERN RAILWAY (gauge, 4 feet 8½ inches).—In December, 1894, Mr. E. A. Handy, chief engineer, stated that half a dozen of the Golder steel ties had been recently placed in the main track near Cleveland. The track is ballasted with gravel, and the traffic over it is about 1,200 cars per day. The tie is a shallow inverted trough with flaring sides, and having an opening on each side of each rail seat through which projects the vertical leg of a Z-iron whose horizontal web (not exactly horizontal, but sloping down so that the upright leg is inclined away from the rail) lies inside the trough. Through a slot in the upright leg passes the forked or slotted end of a rail clamp which is held to the tie by a vertical bolt. The tie is about 8 feet long, one-half inch thick, 6 inches wide on top, and 12 inches on the bottom.

LONG ISLAND RAILWAY.*—Since the date of my original report an experiment has been made with the Standard steel ties for about three years. There were 500 ties laid for the trial, 16 ties to a rail length of 30 feet. Half of them were laid in the tangent approaching a 3-degree curve, and the other half on the curve, continuous with the first half. With an elevation of 4 inches for the outer rail on the curve, for an average speed of 45 miles per hour (no train exceeding 48 miles per hour as a maximum), the track with Standard ties showed a decided tendency to shift outwardly in line. With an ordinary elevation of 1 inch or less per degree, it was thought considerable trouble and expense might be expected in keeping track in proper line on curves with these ties, though, as noted in regard to the ties on the Delaware and Hudson Railway, the manner of ballasting would have a considerable influence in this respect. The traffic over the ties averaged about 130 trains per day throughout the year. The wear on the ties from the traffic has been very small, not nearly as serious as oxidation.

The fastenings of the rails to the ties have given no trouble, and are considered efficient. The joint fastenings (see Pl. 30 of original report) were not a success, as they did not hold the rail ends together in track inclined to "creep." Trouble was experienced from this cause immediately after the ties were put in, and at the end of 18 months the joint ties were replaced with ordinary wooden ties, and angle splice bars put on the rail joints. In the three years the cost of maintenance has been about 30 per cent greater than it would have been with wooden ties, owing in great part to the trouble with the joints. The stability of the track, depending so much on the joints, has been defective from the same cause. The experience with these steel ties, therefore, can hardly be taken into consideration in forming a fair judgment as to their efficiency, since the inefficiency of the joints was so great as to vitiate the value of the test, at least during the first eighteen months. Since putting in the wooden joint ties and the angle splice bars the result has been much more satisfactory. All these ties have been recently removed from their first location on account of interfering with the track circuit of a new block signal system. The New York Central Railroad has had similar trouble, as noted further on, and this brings out a new element to be considered in the adoption of metal ties where the block system is in use.

NEW YORK CENTRAL AND HUDSON RIVER RAILWAY.*—After the successful results in point of maintenance which attended the use of the 800 Hartford ties laid in November, 1889, it was decided to use steel ties on the four-track line forming the approach to the Grand Central Station in New York, including the Harlem tunnel. On this line, over which run the trains of all the railways having access to the terminal station, there is an enormous traffic of regular trains, as well as of empty trains and light engines running between the station and the yards and the roundhouses at Mott Haven, the total number of train movements (including regular and empty trains, engines, etc.), being about 500 per twenty-four hours, and about three-fourths of this traffic is during the day hours. There is, consequently, much difficulty and waste of time (involving considerable expense) in effecting maintenance work and renewals to track, especially in the tunnel, without interfering with the traffic, and one of the principal reasons for adopting steel ties was to secure a permanent and substantial track and thus effect a decided economy in the amount and cost of track work, both for labor and material. The track consists of 100-pound rails with 3-tie supported joints spliced by 36-inch angle bars and six bolts, and these are now laid on wooden ties in broken stone ballast.

In 1892 a contract was let to the Railway Improvement Company, of Chicago, for 33,500 steel ties of the modified Hartford type, differing considerably from those first used and having an improved bolted clamp fastening designed by Mr. Walter Katte, chief engineer of the road. About 18,000 of these ties have been manufactured by the Schoen Manufacturing Company, of Pittsburg, but the laying of these in the track has been delayed for the reason, mainly, that the use of the "track circuit" in the operation of the block signal system made it necessary to provide for some effective mode of insulating the rail from the tie, and though this has been devised the company does not, apparently, at this time deem it expedient to incur the additional very heavy expense for such electric insulation. The steel ties are to be laid on the four tracks between Fifty-sixth street and One hundred and tenth street. On the new four-track steel viaduct thence to Mott Haven the rails will be bolted direct to the steel troughs of the floor system. The ties will be entirely covered with the stone ballast, except at the rail seats, so as to leave the bolted clamps exposed. From the outer clamps the ballast will be extended straight across to the next track or to the side of the roadbed, thus forming a good shoulder to keep the track in line. Between the rails the ballast will be crowned 3 inches, thus giving a depth of 6 inches over the middle of the tie, which is depressed, as shown in plate 31. An insulating system has been devised, but is understood to be somewhat expensive.

The tie (Pl. 1) is pressed from a steel plate one-fourth inch thick, and weighs about 100 pounds, including fastenings. The plate is of Bessemer steel, with 0.10 per cent carbon, being necessarily soft in order to stand the hydraulic drop-forge method of manufacture. Its original size is 8 feet 4 inches long and 13⅝ inches wide. The finished tie is 7 feet 10 inches long, with the ends turned down and the middle bent down 3 inches with a curve of 3 feet 10 inches radius. The extreme width at the ends is 10 inches. At the middle the trough section is 6 inches wide at the top, 8¾ inches wide at the bottom, and 3½ inches deep. At the rail seats it is 7 inches wide on top, 10 inches wide on the bottom, and 2¼ inches deep. There are four bolt holes fifteen-sixteenth inch square, and each rail is held by two clamps with seven-eighth inch bolts, having the shank bent at an angle to the head. In this way a wedging grip is obtained upon the rail flange, and the clamp has a slotted hole so that the gauge can be adjusted as required. It was at first proposed to stamp a pocket at each side of each rail seat, the bottom of pocket sloping down from the rail and having the bolt hole, so that a straight bolt could be used and would lie at an angle with the rail. A much better arrangement is that actually adopted, by which the pockets are avoided and bent bolts are used. A washer is used to prevent the edges of the nut from catching in the slotted hole, but no nut lock is used, the use of the Harvey grip-thread bolt enabling this to be dispensed with. The cost was about $2.50 per tie, but would be less now, probably less than $2. The tie weighs 92 pounds, or 100 pounds with attachments.

In regard to the 800 ties laid in 1889, Mr. Katte stated in April, 1894, that after four and a half years' service they were still giving very excellent satisfaction, while the cost of maintenance of them was at a minimum. He considers the new design a great improvement upon these. Of the four arrangements of spacing the older ties those with a uniform spacing between the ties were at first considered to give the best results. The first report of the roadmaster gave some unfavorable opinions, due partly to the fact that the track had not settled thoroughly together, but subsequent experience has been very satisfactory, both as to economy and efficiency. The general experience in other countries is that the trouble and expense of maintenance is greater with metal ties than with wooden ties for the first year or two, after which it tends to reduce very considerably. The following is the substance of two reports by Mr. O. W. Eggleston, assistant general roadmaster, made to the chief engineer:

(March, 1891.) In relation to the Hartford steel cross ties laid on the Hudson River division, near Garrisons, N. Y., I find that the result of our work, which was done previous to December 10, on these ties has been very satisfactory since that date. We have had very little to do in order to properly maintain them since December, and that which we did have to do was where the ties are spaced 3 feet, center to center. I believe that this distance is too great for ties on a road with such heavy traffic as our road. The even spacing of 2 feet $1\frac{1}{16}$ inches for the entire length of the rail has so far shown the best results. The ties are now holding to good line and surface and the clip bolts are remaining in good, tight condition, with but very few exceptions. In fact, it is my opinion that we have the ties now in such condition that they can be maintained at very little expense in the future.

> (November, 1893). At this date these ties are all in good shape as to line and surface, and the bolts are in good, tight condition. Since the last report, made February 1, 1892, we have noticed no perceptible change in the condition of these ties, excepting that it is necessary to tamp them up occasionally when they become loose. The cost of the labor in so doing since February 1, 1892, is $75.94, which averages about 4.7 cents per tie each year. The last report was a fraction over 5 cents, indicating that the condition of these ties is really improving. During the past two years we have renewed 58 of the clip bolts, which were twisted off in trying to screw them up tight. The labor cost of this, which is included in the above-mentioned sum ($75.94), is $8.81, or say $4.40 per year; 58 bolts equals about 1.8 per cent of the whole number, indicating a yearly renewal of bolts of only about 0.9 per cent, which I regard as a very good showing. During the early part of last spring a freight car was derailed and ran over the entire length of these ties, causing slight marking and denting near the center of the ties, but otherwise doing no damage. I regard this on the whole as a very excellent showing for these ties, and in the improved model, such as those we now have on hand for the Fourth avenue tunnel tracks, being depressed in the center and covered by ballast, the injury above reported by wheels off track will not occur.

On October 18, 1894, Mr. Katte, chief engineer, wrote that, according to his annual custom, he had just had taken up for examination one of the Hartford steel ties laid in the main track on the Hudson River division near Garrison station, and had received the following report upon it from Mr. O. W. Eggleston, assistant general roadmaster:

> The tie is in very good condition. Very little corrosion in spots on underside of tie. At the point where the rail comes in contact with the tie between the bolt holes there is perceptible a slight wear on the outer edge of rail base. The bolts are in good condition. I think on the whole that the tie "shows up" very favorably for the five years' service they have now had.

Some of the Saunders ties were laid in the Grand Central station yard, New York, and in June, 1893, the supervisor of the yard stated that they were giving satisfaction after twenty-two months' service under switching engines and cars, and that the ordinary spikes driven into the curved holes in the rail blocks had not loosened. These ties are described further on.

New York, Lake Erie and Western Railway.—A few of the Daniels steel ties (*see* Pl. 2), described further on, have been tried on a side track, and I am indebted to Mr. A. Mordecai, chief engineer, for the following communications respecting the same:

> We have 17 of the first pattern of Daniels' steel tie, which were laid in one of our side tracks in the Youngstown yard. The ties were put in service in November, 1891. The tie is of much lighter pattern and entirely different style of fastening from the present tie made by the Daniels Steel Railway Tie Company. I am not in a position to judge of the merits of the new pattern of tie, but the old pattern of tie which we have in track did not give satisfaction, the ties being so light that several of them broke off under the rail, and the corrugations were flattened out. (*J. W. Fawcett, division roadmaster.*)
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> I would not consider the fact that some of these ties have seemed to answer the purpose as furnishing a sufficiently comprehensive test on which to base any claim as to the merits of these ties. (*J. W. Morris, general roadmaster.*)

Pennsylvania Railway.*—This road, as noted in my original report, has tried some of the Webb ties used in England on the London and Northwestern Railway (using also the English bullhead rail), but the ends are open, and although the ties are covered with ballast, they shift laterally in the track, so that where used on the New York division timbers have been put in between the ends of some of the steel ties and the wooden ties on the opposite track, so as to hold the former in line. Some channel ties with riveted connections, and costing no less than $4 each, have been tried, but were too weak for the service, and they were removed from the main track. Some of these were put in a switch track in the Philadelphia yard, where I saw them in 1891, and they were then bent all out of shape. It will be seen, therefore, that the experiments on this road were entirely too limited to admit of any conclusions being drawn as to the efficiency of metal ties in general. In 1892, however, the daily papers made various statements to the effect that the Pennsylvania Railroad was abandoning metal ties after having experimented with them for fifteen years, and drew conclusions that metal ties were a failure. These conclusions have no doubt had some effect on the public mind, and even upon some engineers not well informed as to the facts. As a matter of fact, the limited trials were of little significance, and the broad conclusions were groundless, especially in view of the generally satisfactory and successful results obtained in long experience on several thousands of miles of railway in other countries, as well as on the New York Central Railway and the Chicago and Western Indiana Railway in this country.

PHILADELPHIA AND READING RAILWAY.—Trials of the Price, Standard, and Bonzano metal ties have been mentioned in the daily press and elsewhere, but Mr. H. K. Nichols, chief engineer, informed me in July, 1894, that he knew of no other than the Price ties being used, and of these he furnished particulars. The Price metal ties (*see* Pl. 2) were laid June 9, 1893, for 300 feet (level tangent) on the Germantown branch, the work being in charge of Mr. Louis Blackstone, division engineer of the Philadelphia and New York division. The traffic is both freight and passenger, with engines weighing 50 to 75 tons (25 to 45 tons on the driving wheels). The tie is composed of two angle irons, one-fourth by 2 by 3 inches, with a space of 3 inches between them, the tie being 7 feet 6 inches long, 8¼ inches wide, and weighing 100 pounds complete. The material is wrought iron, with riveted malleable iron brackets on top and three diaphragms across the interior to prevent lateral shifting. There are 16 ties to a rail length of 30 feet. The rails rest on wooden bearing blocks between the brackets and are secured by malleable-iron clamps, which embrace the rail flange and edge of tie and are held together by a horizontal bolt through the block. The ties are painted. They were manufactured by the Price Railway Appliance Company, of Philadelphia, and cost $2.75 each, including fittings, f. o. b. at the factory. They are laid in ballast of good hard furnace slag, and carry 80-pound rails. They have not been in service long enough to warrant an expression of opinion as to the practical results. First-class white oak ties on this road cost 70 cents each, as an average, and have an average life of seven years but the life of a wooden tie depends as much on its wearing quality as on any effect produced by the weather. The climate is variable, and not unfavorable for wood or iron.

In April, 1894, Mr. James M. Price, the inventor, wrote as follows in regard to these ties in particular, and details of his other forms of ties will be found further on:

> There were 200 of our No. 3 metallic ties furnished to the Reading Railroad in May of 1893, and the majority of them were placed in the track east of Wayne Junction, and have been carrying there all incoming passenger trains (185 per day, including, I think, two 100-ton locomotives) now for nearly eleven months. They stand well up to their work and appear to be as good as on the day they were laid. The rest were at that time reserved, as we were told, to place upon a curve; but there have been large changes in the administration of that road within that time, and I have no knowledge that they have been laid. They much surprised the trackmen in several particulars. They found, after an hour's work in laying them, that they could lay them nearly twice as fast as they did wooden ties; and when in a few days the foreman came by expecting to dress them up with further tamping, as usual after a few days' use with wooden ties, he found them in such substantial shape that he passed them by. Indeed they never have had the final filling with fine ballast and slight mounding between the rails which was intended to be done for them. They will hold the track absolutely upon any curves in which wooden ties would do it with the same ballast which would hold wooden ties upon the severest curves.

In the summer of 1891 about 1,000 of the Standard steel ties were laid for a length of about three-fourths of a mile in the main track at Philadelphia, and it was reported that the results were so successful that the railway company placed orders with the Standard Steel Tie Construction Company of New York for more of these ties, to be used at ash tracks at the furnaces along the road. The point selected for the trial, near Philadelphia, was between Columbia avenue and Sixteenth street, where there was an average traffic of 260 trains per day. The ties carried 80-pound rails and were laid in slag ballast. In July, 1894, Mr. E. C. Tomlinson, superintendent of the Philadelphia and New York division, wrote me as follows in regard to these ties:

> The number of the Standard metal ties on this road was originally 1,000, but latterly only 500. There were 16 ties to a rail length of 30 feet, making 1,875 feet of track. The rail fastenings were fairly efficient, but there was no appliance to prevent the rails from creeping. The ties were very unstable, working up and down in the track, and the track also was unstable, difficult to keep in line and surface. The cost of maintenance of the metal ties, while they lasted, was about the same as wooden ties, but the conditions were too dissimilar for comparison with the cost for wooden ties, as the steel ties would have to be renewed two or three times during the life of a white oak tie.

PHILADELPHIA, WILMINGTON AND BALTIMORE RAILWAY.*—The statement in my former report as to the unsatisfactory results which attended the use of the Travis iron ties on the old Philadelphia and Baltimore Central Railway led to some criticism from Mr. Brandwood, who had patented an improved form of tie of this type, designed to meet the objections experienced with the original Travis tie. Further inquiry, however, confirmed the statements as to the original tie, as shown by the following letters, sent to me in June, 1891:

> I have taken up the matter with our engineer in order to confirm the impression remaining in my mind relative to experiments with metallic cross-ties near Claymont, Del. The report formerly made on this subject does not, so far as I am aware, need any material change. It was made with great care, and was intended to be a frank statement of our actual experience. There is nothing, therefore, to change. I am free to say, however, that information reaches me indirectly to the effect that more or less improvement has been made in the tie since our experiments. The owners of the device should have the benefit of any such improvements without doubt, but you will readily perceive I am not in a position to speak advisedly on the subject, not being familiar with any advances that have been made. (*H. F. Kenney, general superintendent, June 8, 1891.*)
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> I have to say that the experimental Travis ties placed in the main tracks of this company, and to which General Superintendent Kenney's communication refers, failed to give satisfactory results, for the reason that their constituent parts were badly proportioned, and for the further reason that the owners or manufacturer failed to give them any attention during the test. I am informed that a number of improvements have been made in this tie since the test, and possibly the defective features may have been remedied. (*A. Feldpauche, engineer of maintenance of way, June 19, 1891.*)

RICHMOND AND DANVILLE RAILWAY.—Two of the Hammond steel ties with keyed clamp fastenings were laid in 1890 and 1891, and reported in good condition in 1894. They are described further on.

TERRE HAUTE STREET RAILWAY (gauge, 4 feet 8½ inches).—At Terre Haute, Ind., the electric railway company has this year laid an all-steel track on Ninth street, a business street leading from Wabash avenue and Main street to the union station. The Daniels tie is used, a description of which is given farther on, and is laid in a concrete foundation.

After the necessary excavation the ground was rolled with a 14-ton steam road roller. Then 8 inches of broken-stone concrete was placed in position and allowed to set. Then the rails, ties, and joints were distributed and connected together, and the track brought to the required grade by putting blocks under the rails at intervals. Then 4 inches of concrete were tamped under the ties and under the rails, the inequalities of the surface filled with concrete, and the whole leveled up with concrete over the tops of the ties and pounded to a level surface with a wooden rammer and allowed to set.

The ties are steel, double corrugated, and heavily coated with tar while hot. They are 2 inches high, 7 inches wide, and 7 feet long for straight line work, and are laid 15 inches center to center. For special work the ties vary in length as the necessities require, up to 20 feet or more. The metal is one-half inch thick. The ties were manufactured by the Daniels Steel Tie Company, of Youngstown, Ohio. The rails are fastened to the ties by clamps with off-sets to fit the base of rail. These clamps are secured and adjusted to the top of the tie by specially made bolts with oval shoulders, inserted from below the tie, with the head below and the nut on top, a box wrench being used to screw up the nuts.

In using these steel ties in connection with the Wheeler rail joint a mechanical difficulty arose, as the Wheeler joint has a thickness of 3 inches below the rail base, and in laying track with rails breaking joint a straight tie would not answer. At first it was thought it would be necessary to use a wooden tie under the joints, but this was avoided by devising a special joint tie, which was adjusted to the necessary levels by bending it down in the center 3 inches by an easy off-set. In laying the track these special ties were easily placed in position and gave perfect satisfaction. The clamps and bolts were the same as on straight line work. The joint consists of two parts, one of which is keyed onto the other. The larger or heavier part, used on the outside of the rail, has two lugs that fit in the angle-joint holes nearest the ends of rails. After it is placed in position the lighter part is keyed on with a large maul, and it holds the rails rigid. Then the tie is placed under the joint and is fastened to it in the regular way, with the exception that the bolted clamps have longer off sets.

The Illinois Steel Company's 72-pound "Shanghai" T-rail is used, being 6 inches high, with 5 inches base; the head is 2⅜ inches wide. The high web permits the rail to rest on the ties and brings the top of rail to proper level for paving with brick, asphalt, or granite blocks. In this track the rails are laid with broken joints. The paving is of brick, specially shaped bricks being used along the inner or gauge side of the rail head.

TIES.

Bonzano tie.—The steel tie designed and patented in 1892 by Mr. M. F. Bonzano, assistant general superintendent of the Philadelphia and Reading Railway, was of inverted trough or channel section, with vertical sides and narrow bottom flanges. At 5 inches from each end of the tie, and at about 12 or 15 inches from the inside of each rail, the top table was cut away for a width of 5 inches, and the loosened parts were bent down to obtain a hold in the ballast. The end closing pieces extended the full depth of the tie, and the others extended about 3 inches below the bottom of the tie, which was an awkward arrangement. The tie was to be 8 feet long, 8 inches wide over the sides, 10 inches wide over the bottom flanges, and 3½ inches deep. The metal was to be three-eighths inch thick for heavy track and one-fourth inch for light track, the weight being 140 pounds for the former and 105 pounds for the latter, and the cost being $2.25 and $1.65, respectively. Each rail was fastened by a 1-inch U-bolt, having its horizontal leg inside the tie, with a grooved bearing piece or washer between it and the underside of the top table of the tie. The bolt lay diagonally across the tie, its vertical ends passing through round holes and having clamps bearing on the tie and rail flange, the nuts screwing down on the clamps. At the rail joints it was proposed to use special angle splice bars with wide flanges, the bolts passing through these flanges. The ties were to be spaced 2 feet 6 inches center to center. I have not been able to learn of the ties being made or used, but am informed that they were never tried on the Philadelphia and Reading Railroad (United States patents Nos. 437,476 and 441,926.)

Brandwood tie.—This was designed as an improvement on the Travis tie, tried on the Philadelphia, Wilmington and Baltimore Railway. It is a cross-tie of iron or steel, having a cross-shaped section at the middle, with the ends of the horizontal part turned down. At each end of the tie is formed a hollow "box" deeper than the other portions of the tie, and the horizontal part of the tie is widened at the ends to form a plate around each box and to give ample bearing on the ballast. The bottom of the box is closed and has a rib of Λ-section under the rail. Each rail is carried on two clamps, the top of which is of ⊂-shape to hold the rail flange, and has a long lower leg of wedge form which fits into the box. The rib in the bottom of the box forces the lower legs of the clamps apart, causing the upper part to grip the rail tightly, especially when the weight of a train comes upon the rails. Wooden blocks are placed between the backs of the wedges and the sides of the box. At rail joints the upper part of the clamps is made of extra length, to give a good hold on the rail ends. No splice bars or bolts are used. The "box" is rather wider at the middle than at the sides, so that in renewals the clamps may be easily knocked loose from the sides of the box and withdrawn, thus obviating one of the defects said to exist with the Travis tie, that the clamps became wedged so tightly in the boxes that they could not be removed. This tie was designed by Mr. E. Brandwood, of Philadelphia, Pa., and patented December 9, 1890. (United States patent No. 442,416.)

Callahan tie.—This consists essentially of two plates the full length of the tie, with the upper edges notched to interlock or dovetail with the plates inclined together at an angle of 45°, and forming a Λ in cross section. The plates are held by lugs and split keys, and are cut away at the top for the rail; lugs or brackets on each plate forming the rail seat, and the rail being gripped by locking lugs which press tighter as the weight of trains tends to spread the plates apart. In laying track, a tie is first put on at each end of the rail. The two plates of each intermediate tie are then put on, one slipped on from the right and the other from the left, bringing the lugs and notches into engagement, when the plates are opened out at the bottom, filled with ballast, and tamped. The cost was estimated at $2 per tie. (Patent No. 440465. November 11, 1890.) It is the invention of J. J. Callahan, of Newburg, N. Y.

Cannon tie.—This is intended to utilize old rails and resembles somewhat the Z-bar tie (*see* Belgium). Two inverted rails are riveted together, with the outer half of each rail chair between them. The track rails rest on the tie, with the outer edge of the flange entering the fixed part of the chair, while the inner edge is held by a movable chair or clamp bolted to the fixed chair by one bolt under the rail and parallel with the tie. The chairs and a middle spring piece offer resistance to lateral motion when the tie is packed with ballast. It was designed in 1891 by E. A. Cannon, of Minneapolis, Minn.

Columbian tie.—This is a modification of the Taylor tie, and is being put forward by the American Railway Maintenance Syndicate, of Philadelphia, although the original and practically identical form of tie seems to have proved a failure on the Atchison, Topeka and Santa Fe Railway, according to the official statements given on a previous page. It is claimed that "in construction they are perfect simplicity, having neither bolts, rivets, nor keys;" but the tie would probably be the better for one or other of these forms of attachments, as the present rail fastening by lugs on the bearing pieces and on the tiebars do not promise sufficient security. The two bedplates are 12 inches long, 10 inches wide at the top, flaring to 15 inches wide at the bottom, each forming a channel or trough parallel with the rail, and having the inner flange cut away to admit of tamping. They are slotted to admit a tiebar of ⊥-section, 4 inches high and 3 inches wide, which passes through both bedplates or troughs. The joint ties have bearing pieces 20 inches long (parallel with the rail) and have two angle-iron tiebars instead of the inverted T-tiebar. Two lugs on the top of each bearing piece hold the inner edge of the rail flange, the joint bearers having three lugs, while the end of the tiebar grips the outer edge of the rail flange. The ordinary tie weighs 85 to 90 pounds and the joint tie 120 to 125 pounds. It is claimed that they may be placed 2 feet 6 inches center to center, leaving 18 inches between the bearing pieces. Special designs have been prepared for elevated railways and to carry switches and cross-over tracks. (United States patents Nos. 461776 and 525927.)

Crane tie.—This is a cross-tie of cast iron or steel, of ⊥-section, with horizontal top plates for the rail seats, to which the rails are secured by a fixed clamp on the outside and a bolted clamp on the inside. The inventor gives the width of base as 9 inches, and estimates the weight at 125 pounds. (Patent No. 467790, January 26, 1892.) It is the invention of J. J. Crane, of Summertown, Tenn.

Daniels tie.—This is the invention of Robert E. Daniels, and the Daniels Steel Railway Tie Company, of Youngstown, Ohio, has been organized to push its introduction. Some of the ties have been in service for over two years in the Youngstown yard of the New York, Lake Erie and Western Railway, and were favorably reported upon by the yard masters in 1891 and 1892, but the road master's report in 1894 is unfavorable, as already shown. According to a statement furnished in August, 1894, the standard tie for steam railway service (*see* Pl. 2) is 7 feet 10 inches long, 7$\frac{3}{4}$ inches wide, and weighs 80 to 84 pounds. It is a plate rolled with two lengthwise corrugations, forming an upper channel eleven-sixteenths inch deep and two lower channels nineteen thirty-seconds inch deep, its total depth being 1$\frac{1}{16}$ inches. The sides and middle are three-eighths inch thick, and the upper corrugations, upon which the rails rest are fifteen thirty-seconds inch thick. The rails are secured by two clamps, each bolted to the bottom of the tie, between the corrugations, by one five-eighths inch bolt. For street-railway service they are proposed to be 7 feet long, 7 inches wide, and one-fourth and eleven thirty-seconds inch thick, weighing 56 to 60 pounds. A "tie anchor" is used to prevent lateral shifting on curves, and consists of an arched piece of similar section to the tie fastened underneath the rail seats. Mr. Thomp Burton, president and manager of the company, wrote as follows in June, 1894:

"Just when we were prepared to manufacture and had several orders booked for our 60-pound street-railway tie, the coal strike came on here, and we have been unable to make even a single sample tie during the past month. I have been obliged to refuse to contract for filling any orders until the strike is ended and to cancel the orders we had on hand, all except the one for some 4,000 or 5,000 ties for Russell B. Harrison for his Terre Haute street railway lines, as there he has been able to get an extension of time for the completion of his road, the city authorities appreciating the situation due to the coal famine. I have not solicited any orders for our heavy tie, preferring to concentrate my efforts to introduce the Daniels tie for street railway construction. We are selling the 60-pound ties at 66 and 67 cents each, according to the number of ties ordered. The clamps weigh 9 ounces each, while each nut and bolt weighs a fraction less than 5 ounces. We supply them in connection with the tie at cost price, which is $2.90 per 100 pounds for the nuts and bolts and $1.75 per 100 pounds for the clamps. This makes the four clamps and four nuts and bolts for each tie cost a fraction less than 8 cents, making a total of 74 cents f. o. b. at Youngstown for each tie with its fastenings. In the case of prospective work at Cincinnati, the use of the Daniels tie saves at least 40 per cent in excavation and an equal percentage in concrete for the roadbed, under the specifications and requirements of the city engineer. This economy of excavation in original construction I find to be a strong argument in favor of the use of our tie."

The ties are said to be rolled from selected old steel rails, and immediately upon coming from the rolls they are sheared to the required length and then plunged in a tank of boiling tar, where they remain for some hours. (United States patents Nos. 482997 and 522974.)

The description of the street railway track laid with these ties at Terre Haute, Ind., is given on another page. They have also been laid for a length of one block at Newcastle, Pa., and 200 are to be laid shortly at Cincinnati, Ohio. In an improved form of the tie anchor, the anchor is punched on a level face surface the same as the tie, the same bolt attaching the anchor and the rail clamp to the tie. For electric railways, whether with concrete or other ballast, it is considered that the tie 7 feet long, 7 inches wide, and weighing approximately 8 pounds per foot, will meet all requirements. At the present time the ties weighing 60 pounds or less are sold at $1\frac{1}{9}$ cents per pound (free on board at the works) and those over 60 pounds at $1\frac{1}{10}$ cents per pound. As the fastenings for street-railway ties, including the four bolts, nuts, and clamps, cost but 8 cents for each tie, the tie can be sold at not to exceed 70 cents, with fastenings, f. o. b., and the tie of 80 to 90 pounds weight for steam railways at a cost not to exceed $1 per tie. The anchors are only required on steam railways and on curves. Their cost per pound is the same as that of the tie, or about 16 cents per anchor.

Glynn tie.—The tie patented by M. A. Glynn, of Havana, Cuba, is cross-shaped in section, having the upper rib cut away at the rail seat to allow the rail to rest on the horizontal flange. The clamps are driven sideways across the tie, fitting under the upper rib and bearing upon the horizontal flange and the rail flange. A spike or stud through the clamp and tie holds the former in position. In another design the clamps are dispensed with, the notches in the upper rib of the tie conforming to the shape of the rail flange and the rail being rolled with a flange of varying width so that the tie can be put on below at the narrow part and then driven along until it wedges firmly upon the wider part of the flange.

Gottlieb tie.—The tie patented in 1885 by the late Mr. Abraham Gottlieb, civil engineer, was of inverted trough section, with the lower parts of the sides vertical, and having a V-shaped groove rolled in the top table. The section proposed was 7 inches wide on top, 10 inches on the bottom, and $4\frac{1}{2}$ inches deep. The sides were vertical for one-half inch from the top, then sloped out $1\frac{1}{2}$ inches in a depth of $1\frac{3}{4}$ inches, and then dropped vertically $2\frac{1}{4}$ inches. The groove was $1\frac{1}{2}$ inches wide on top and about 1 inch deep. The metal was five-sixteenths inch thick at the top and sides, decreasing to one-fourth inch at the bottom edges. A flat plate on edge, with the ends bent at right angles, was riveted to the vertical sides at each end of the tie, and a third plate at the middle. The tie was 8 feet long and weighed 170 pounds, including the fastenings. At each rail seat were two slots at an angle of 45 degrees with the track, the inner slot being on one side and the outer slot on the other side of the longitudinal groove. Both slots at each seat were inclined in the same direction. Under each rail were two locking plates or tie plates, each having a lug fitting over the side of the tie and a slot at right angles to the slot in the tie. A hook-head bolt was used, the body of the bolt passing through the tie, locking plate, and a rail clamp upon which the nut bore.

Hammond tie.—The tie designed by Mr. C. P. Hammond, superintendent of the Atlanta and Charlotte division of the Richmond and Danville Railway (and now chief engineer of the Savannah, Americus and Montgomery Railway, at Americus, Ga.), is a steel cross-tie of trough section, with flaring sides, and having the top table cut away and bent down to close the ends. It is of $\frac{3}{8}$-inch steel, and weighs 120 pounds. At each rail seat are two T-shaped slots extending from the sides of the tie, one leg of the slot inclining slightly toward the rail and the other at right angles to and extending to the rail seat. A clamp with grooved edges, engaging with the thickness of the tie, is slipped into the slot and along the cross slot till it bears upon the rail, and a similarly grooved taper piece or key is then driven in the slot, bearing against the back of the clamp and driving it firmly up against the rail. The key or wedge is slightly twisted or warped, the key being thus sprung and locked, so that a close fit is not necessary, and there is no liability of the key getting loose or slacking back. In answer to my objections that cracks would be very likely to start from the edges and corners of the slots, and that the parts would be liable to rust together, especially in the grooves, Mr. Hammond replies that the holes will be rounded, and that a tap of the hammer would easily break through the rust; but I am inclined to think that in case of rail renewals, etc., it would be found difficult to get the fastenings off, owing to the rusting of the grooves and edges. This, however, might be provided for by tarring the fastenings. In April, 1892, Mr. Hammond stated that he had had two ties made, one of which had been in the track of the Richmond and Danville Railway for two years, and the other one year, and he found that even with a roughly-made tie and a loose-fitting key or wedge the fastening kept perfectly tight. In May, 1894, he wrote that the wedges were then as tight as when they were put on, four years ago, while the tie was also in good condition. (Patents Nos. 463045 and 463046, November 10, 1891.) A modification designed to meet certain objections as to difficulty in tamping the inverted trough tie is a hollow box tie, with flat top and bottom and flaring sides, made from one plate, bent to shape, the ends interlocking along one of the lower edges, no riveting being required. The fastenings are as already described.

Hartford tie.—The original tie and patents were noted in my former report, and the modified form made for the New York Central Railway has been described a few pages back. Another form, however, is designed with a pocket 2⅛ by 2¾ inches, stamped on each side of each rail seat, the bottom of the pocket and top of rail clamp being inclined 4 to 1, so that a straight bolt would be inclined away from the rail instead of using a bent bolt, as in the ties actually made for the New York Central Railway. The bolt hole in the bottom of the pocket was to be $1\frac{1}{16}$ inches square, to fit the 1-inch square neck of the bolt. (*See, also*, patents Nos. 467166, and 487733.) These patents are owned by the Railway Improvement Company of Chicago.

Heller tie.—A tie proposed in 1891 by D. C. Heller, of Reading, Pa., was of T-section, wider and deeper at the ends than at the middle. Under the rail seat was a box-shaped recess, open on top, in which was fitted a wooden bearing block. The edge of the "box" projected above the flat top of the tie and formed two lugs to lap over the outer flange of the rail, while the inner side was held by an ordinary spike driven into the block.

Hunt ties.—These are light steel ties of trough section used for industrial and portable railways for plantations, factories, steel works, etc., by the C. W. Hunt Company, of New York. The usual gauge is 21½ inches (but varies up to 30 inches) over the outside of rail heads, the engine and car wheels having outside flanges. The track is made in sections 20 feet long, with T-rails of 12, 16, or 20 pounds per yard, on steel ties spaced 24½ inches center to center. The ties are about 34 inches long, with closed ends. Each rail is attached by two rivets having hooked ends which fit over the rail flanges, the rivet heads being inside the tie. The ties are usually 34 inches long, 6 inches wide, and 1 inch deep, with metal from one-eighth to three-sixteenths inch thick, and the weight is from 9 to 15 pounds per tie complete. Soft steel is used, having an elastic limit of not less than 32,000 pounds. The rivets are three-fourths inch diameter. It is estimated that about 30 to 35 miles of this track have been built, using 80,000 to 90,000 steel ties, usually spaced 24 inches center to center. It is used principally in manufacturing establishments, gas works, coal yards, and other places where good alinement, smoothness, and permanence of track are desired.

Kinnear tie.—This is a tie with an "automatic clutch" fastening for the rail, designed by W. R. Kinnear, of Columbus, Ohio. The tie is of T-section, with the width of base and height of web increased at the rail seat and having several fillets connecting the flat base and web. It is weakened, however, by cutting away the material of the web at the rail seat to admit the movable rail chairs, which straddle the web and bear against the rounded projections formed by the ends of the notches cut in the web, which projections are designed to act as hinges upon which the chairs or jaws should turn. The chairs are narrow and give but a small and insufficent bearing to the base of the rail. This chair is intended to give an automatic clutch grip upon the rail, the depression of the rail under the weight of a train causing the two parts to turn on the projections of the web of the tie and thus bear tightly on the web and base of the rail. There is nothing, however, to prevent the rail from rising to its former position when the train has passed, so that there would be a considerable rattling and pounding of the track and rapid wear of the bearing surfaces. The narrowness and motion of the parts upon which the base of the rail rests would almost certainly result in a very severe cutting and wear of the rail. The inventor states that the clutch can be locked by a taper pin driven through the lower part and the web of the tie, and that adjustment of gauge can be effected by the use of special sized clutches, but the use of such special parts is a decided objection in track work. The principle upon which the fastening is designed is ingenious but not new, but the arrangement is not promising for railway track.

Lancaster tie.—This is a trough tie with a strip of metal bent in the form of a W (with horizontal top and bottom lengths) placed inside under each rail seat and riveted to the top table, the idea being to strengthen and stiffen the tie. (United States patent, No. 502464.)

Morrell tie.—This is a steel trough or channel tie, placed with the open side upward, and it resembles the Standard tie described further on. The ties in use on the Delaware, Lackawanna and Western Railway (*see* Pl. 32) were manufactured by the Lackawanna Iron and Steel Company, of Scranton, Pa. The tie is 8 feet long over the bottom, 7 inches wide, and 3 inches deep, the sides being vertical and having the ends cut at an angle. The sides are cut out under the rail for a depth of three-fourths inch to allow the rail to rest directly upon a wooden block within the tie, the block being three-eighths inch less in height than the depth of the channel and as wide as the rail base. The central portion of the bottom of the tie is cut out, and at the ends of this opening the bottom is bent down vertically, so as to afford resistance to lateral motion. The wooden blocks are treated by a preservative process and are placed with the grain vertical. Vulcanite blocks have also been tried. On the outside of the block is a steel plate the full width of the tie, the ends fitting into the notches in the top edges of the tie, thus taking the outward thrust of the rail flange. Each side of the rail is held by a clamp of steel ½ by 3 inches, the lower end of which engages with a hole in the bottom of the tie. The clamp inclines toward the edge of the rail base at an angle of about 45° and has its upper end bent to bear upon the rail flange, while on curves the outer clamps may be bent so as to bear also against the web of the rail, the gauge may be widened by changing the two clamps of one rail. Each clamp is held by a vertical bolt having a hooked head, which passes through a hole in the bottom of the tie, the nut screwing down upon the clamp and the bolt can be put in or taken out without disturbing the tie by merely putting the bolt in a horizontal position so as to make the hook projection of the head enter and engage with the bolt hole. (United States patents, Nos. 457500, 457517, 457518, and 483853.)

Pope tie.—The tie designed by J. L. Pope, of Cleveland, Ohio, is of inverted trough section, with nearly vertical sides, and having the ends closed by slitting the sides near the ends and turning down the top table. A lug is stamped up at the outside of each rail seat, fitting over the base of the rail, and the rail seat is slit at each side and at the outer end, against the lug. A tie-plate with inclined bottom face is placed under the rail bending down the rail seat and a C-shaped lug clamps the inner edge of the rail base to the tie plate and tie. When the tie plate and clamp are driven outward toward the end of the tie the outer edge of the rail base is forced tightly under the lug, and the spring of the bent section of the rail seat tends to keep the parts from working loose. It would seem, however, that the cutting loose of the rail seat would seriously weaken the tie and almost inevitably lead to cracks starting at the corners. (United States patent, No. 502830.)

Price tie.—The ties designed by Mr. James M. Price, of Philadelphia, consist essentially of two angle irons with riveted malleable iron brackets on top and diaphragms below (*see* Pl. 2) resembling in general form the Hicks tie, tried on the Delaware, Lackawanna and Western Railway (p. 287 and Pl. 30 of my original report), but having C-shaped clamps, held together by a horizontal bolt under the rail. Some of these ties have been laid on the Philadelphia and Reading Railway, as already noted, and these have wooden blocks under the rails, fitting between the riveted brackets. In later designs these blocks are eliminated, the rails resting on malleable iron bearing plates, the edges of which rest upon ribs on the brackets. This brings the rail lower down upon the tie. The clamps bear upon the top of the rail flange and upon the under side of a base plate riveted inside the tie. This base plate has also a transverse rib the full depth of the tie to prevent lateral motion. The inventor claims that any well-appointed railway shop can manufacture the ties for their own roads, requiring only the angle irons and the malleable fittings, which latter are furnished by the Price Railway Appliance Company, of Philadelphia. For use on bridges or elevated railways the tie may be inverted, with the rail seats or blocks resting inside the channel, and the flat bottom of the tie resting on the stringers or girders of the structure. (United States patents, Nos. 427109, 430590, 431172, 462062, 467432, and 503253.)

Saunders tie.—The cross-tie invented and patented by Ellison Saunders, of Austin, Tex., is a flat plate with a block of cast or malleable iron attached near each end by bolts or rivets. These blocks form the rail seats, and have spike holes which are not vertical, but twisted or curved. Ordinary spikes are used, and being bent in driving, it is claimed that they will not work loose. To stiffen the flat plate it is trussed by a rod having the ends let into the lower parts of the rail blocks and the middle passing through a block in the middle of the tie. A T-iron is also riveted along the underside of the plate. Some of these ties have been in service for two or three years in the yard of the Grand Central Station, New York, and on the International and Great Northern Railway at Austin, Tex., and have been favorably reported upon by the track masters. In the former case they are said to have stood considerable switching traffic without the spikes loosening their hold. It weighs about 100 pounds and costs $1.25 per tie. (United States patents Nos. 450498, 463456.)

Schoen tie.—The pressed steel tie manufactured by the Schoen Manufacturing Company for the New York Central Railway is sometimes called by the maker's name. (*See*, however, "New York Central Railway" and "Hartford tie," and Pl. 1.)

Sears tie.—A steel tie designed by W. G. Sears, of Washington, D. C., in 1892, is of trough section, with bottom convex upward, sides flaring outward from the bottom, and horizontal flanges on the top edges. A plate across the open trough forms the seat for each rail, being clamped to the edges of the tie, and the rails are held by clamps tightened by horizontal wedges or keys. The troughs would be filled with ballast.

Standard tie.—This tie, which has been described and illustrated in my original report (*see* p. 387, and Pl. 30), consists essentially of an open channel or trough with vertical sides and having a portion of the bottom cut loose and bent upward level with the top of the sides, to offer resistance to lateral motion, the tie being filled with ballast. A block of wood with grain vertical and treated by a preservative process is placed under each rail and the rail is secured by clamps held together by a horizontal bolt through the block. A modified form has the channel laid on its side with a brace of I-section placed inside the channel under each rail seat, the rail resting directly on the upper side of the channel and clamped to it and the I-piece. This, however, is an expensive design to manufacture. The ordinary form of the tie is in use on the Chicago and Western Indiana Railway, Long Island Railway, and Philadelphia and Reading Railway. For use at switches and crossovers a special form of tie has been designed which can be made of any length and admits of the four rails being clamped at any desired point, thus providing for the proper position of the main track and lead rails. All patents on these ties are owned by the Standard Steel Tie Construction Company, of New York.

Straub tie.—This tie was patented by J. W. Straub in 1893, and is put forward by the Straub Safety Metal Tie Company, of Philadelphia. It consists of a flat plate with one edge bent up and the other bent down, while the ends of this lower web are turned in across the tie to offer resistance to lateral motion. Upon the flat part of the plate are riveted two rail chairs of inverted trough section, placed so that the sides will offer resistance to lateral motion when the ballast is filled in over the tie. Underneath the flat plate, and secured by the rivets attaching the chairs, is a hard wooden board, the idea being that this will prevent the ballast from being ground fine, while, owing to the ballast biting into it, it will help to resist the lateral motion. The rails are secured on the chairs by bolted clamps. The ties are proposed to be 7 feet 6 inches long, 7 inches wide, one-fourth inch thick, with chairs three-eighths inch thick. The weight would be 90 pounds and the cost about $2.50 per tie. (United States patent No. 492121.)

Sweet tie.—This tie is the invention of H. P. Sweet, and the Sweet Metal Cross-Tie Company, of Los Angeles, Cal., has been organized to introduce it. It is a steel trough of semicircular cross section with wide horizontal flanges, the trough being laid with the open side upward. At each rail seat a hollow filling piece is placed in the trough, fitting the shape of the tie and having a flat upper part upon which the rail rests. The rails are fastened by ┐-shaped clamps as long as the width of the tie, bolted to each of the horizontal flanges of the tie. The trough may be filled with ballast or left open for drainage. The weight is given as 70 pounds, which would be too light for a main track, and the price is given as $1.50 per tie. The thickness is one-half inch for 10 inches under the rail, and three-sixteenths inch elsewhere. In order to relieve the bolts of the outward thrust of the rail the ends of the clamps fit into notches in the flanges of the tie. On curves a combined clamp and rail brace is used, which allows for a widening of gauge to the extent of 1 inch. The bolts are seven-eighths inch diameter. To resist lateral motion the ends may be cut at the junction of the curved part with the flat flanges, and the latter bent down; or for rock ballast a plate 12 inches wide and 6 inches deep (cut out to fit the trough) may be secured at the end. The ties are 12 inches wide over the flanges and it is proposed to space them 2 feet center to center. (United States patent No. 446899.)

Taylor tie.—This has been taken up by a company and styled the Columbian tie, under which head it has already been noted. (*See also* United States patent No. 461775 in Appendix No. 2.)

Walker tie.—A cross-tie of cast iron or steel patented in 1891 by W. Walker, of Kansas City, Mo., was a flat plate bent down near each end to form a recess or box, wider at the bottom than the top, in which was placed a wooden block. The cast iron tie had a rib between the boxes, this rib being the same depth as the boxes at the middle, and a lug on the outer side of each box held the rail flange. The steel ties had a lug stamped up which would be hammered down upon the rail flange. In both cases spikes were used to hold the inside of the rail.

Ward tie.—In 1893 an inverted trough tie was invented by W. S. Ward, of Philadelphia, as part of a proposed system of track using a flangeless T-rail. At each end of the tie was a narrow U-shaped recess to fit the tapered bottom of the rail web. (United States patent No. 497562.)

TABULAR SUMMARY OF METAL TRACK.

The following tabular statement is a summary of the figures obtained from official returns and published statistics, and presented in the foregoing part of this report. It shows, in brief, that the proportion of track laid with metal ties to the total length of railways throughout the world has increased from 7 per cent in 1890 to nearly 10 per cent in 1894. Excluding the United States and Canada, which have a great railway mileage with an infinitesimally small percentage of metal track, the percentage has increased from 13.2 per cent in 1890 to 17.2 per cent in 1894. Allowing for the incompleteness of the returns, especially in this supplementary report (as it has not been attempted to obtain returns from every railway mentioned in the former report), it appears probable that the actual percentages (exclusive of the United States and Canada) are about 20 per cent for 1894 as compared with 15 per cent in 1890. At the International Railway Congress of 1892, held in Paris, Mr. Kowalski, who has reported several times on the question of metal ties, estimated the railway mileage of the world at 446,000 miles, with about 46,500 miles of metal track, or say 10 per cent. My former report of 1890 gave a total mileage of 362,000 miles, with about 25,000 miles of metal track, or say 7 per cent. The present report of 1894 gives a total mileage of nearly 400,000 miles, with about 35,000 miles of metal track, or 9 per cent. (*See* Letter of Submittal.)

SECTION 1.—*Europe.*

Countries.	Longitudinals.	Cross-ties.	Total, 1894.	Total, 1890.
	Miles.	*Miles.*	*Miles.*	*Miles.*
England	....	73	73	70
France	....	128	128	52
Holland	....	322	322	329
Belgium	....	176	176	115
Germany	3,580	8,025	11,605	8,787
Austria and Hungary	62½	154	216½	123
Bosnia	....	12	12	....
Switzerland	....	480	480	397
Spain*	....	*7	264	*†259
Portugal	....	1	1	⅕
Sweden and Norway*	....	½	*½	*½
Denmark	....	18	18	18
Russia	2	7	9	....
Turkey (Europe)*	....	71	71	71
Turkey (Asia)‡	....	309	309	....
Greece	....	28	28	....
Totals of Europe	3,644½	9,502½	13,404	10,222
Total metal track	....	....	13,404	10,222
Total track	....	....	137,000	132,071

* Taken from my original report of 1890.

† Two hundred and fifty-two miles of this had plate ties.

‡ These 309 miles are not included in the above total, but in the total for section 4, Asia.

SECTION 2.—*Africa.*

Countries.	Bowls and plates.	Cross-ties.	Total, 1894.	Total, 1890.
	Miles.	*Miles.*	*Miles.*	*Miles.*
Egypt	851	39	866	887
Algeria		164	164	120
Abyssinia*		* 14	* 14	* 14
Soudan		2	2	
Senegal		30	30	3
Kongo (Portuguese)		5	5	
Kongo (Free State)		64	64	
Cape Colony	60	60	906	116
South African Republic		115	115	* 40
South Africa* (Portuguese)		* 48	* 48	* 48
East Coast pioneer railways		125	125	
Réunion*	* 62		* 62	* 62
Totals for Africa	973	666	2,401	1,290
Total metal track			2,401	1,290
Total track			5,675	5,200

* Taken from my original report of 1890.

SECTION 3.—*Australasia.*

Countries.	Cross-ties.	Total, 1894.	Total, 1890.
	Miles.	*Miles.*	*Miles.*
Queensland	82	82	40
South Australia	152	152	146
Totals for Australasia	234	234	186
Total metal track		234	186
Total track (7 colonies)		12,000	10,640

SECTION 4.—*Asia.*

Countries.	Bowls and plates.	Cross-ties.	Total, 1894.	Total, 1890.
	Miles.	*Miles.*	*Miles.*	*Miles.*
British India	7,595	6,050	13,655	9,224
Sumatra*		90	90	90
Java*		500	500	500
Straits Settlements		25	25	
China		2	2	
Japan		5	5	
Asia Minor†		309	309	
Totals for Asia	7,595	6,981	14,586	9,314
Total metal track			14,586	9,314
Total track			22,000	19,106

* Taken from my original report of 1890.

† See section 1, Europe (Turkey in Asia.)

SECTION 5.—*South America, Central America, West Indies, and Mexico.*

	Bowls and plates.	Cross-ties.	Total, 1894.	Total, 1890.
	Miles.	*Miles.*	*Miles.*	*Miles.*
Argentine Republic	3,438	200	3,638	3,543
Chile*		1	1	1
Brazil	82	53	135	86
Venezuela		218	218	57
West Indies		204	204	
Mexico	35	185	220	
Totals	3,555	861	4,416	3,764
Total metal track			4,416	3,764
Total track			21,500	20,702

* Taken from my annual report of 1893.

SECTION 6.—*North America.*

Countries.	Cross-ties.	Total, 1894.	Total, 1890.
United States	12	12	2
Canada			
Total	12	12	2
Total metal track (United States, 1894)	12	12	2
Total track	176,000	190,000	174,000

Summary of totals of mileage.

Sections.	Longitudinals.		Bowls and plates.		Cross-ties.		Total metal track.	
	1894.	1890.	1894.	1890.	1894.	1890.	1894.	1890.
No. 1	3,645	3,637	252	252	9,502	6,240	13,404	10,222
No. 2			973	993	590	297	2,326	1,290
No. 3					234	186	234	186
No. 4			7,595	5,312	6,981	4,002	14,586	9,314
No. 5			3,555	3,456	861	332	4,416	3,788
No. 6					12	2	12	2
Totals	3,645	3,637	12,375	10,013	18,154	11,059	34,863	24,802

NOTE.—The use of longitudinal bearings is being abandoned gradually. The bowls and plates (in pairs connected by tie rods) are mainly in service in tropical countries, with special conditions of track and traffic, but these also are being abandoned in favor of metal cross ties. The cross ties are used under conditions of climate, traffic, track, etc., most nearly similar to the conditions obtaining in this country.

Percentage of metal track mileage.

Sections.	Total metal track.		Total track.		Percentage of metal track.	
	1894.	1890.	1894.	1890.	1894.	1890.
	Miles.	*Miles.*	*Miles.*	*Miles.*		
No. 1	13,404	10,222	137,000	132,071	10	7.74
No. 2	2,326	1,290	5,600	5,202	40	24.80
No. 3	234	186	12,000	10,640	2	1.75
No. 4	14,586	9,314	22,000	19,106	66.30	48.75
No. 5	4,416	3,788	21,500	20,702	21	18.30
No. 6	12	2	190,000	174,000		
Totals	34.863	24,802	389,100	361,886	9	6.85
Total mileage of railways with metal track			34,863	24,800		
Total mileage of railways of the world (exclusive of United States and Canada)			198,000	187,721		
Percentage of railways with metal track (exclusive of United States and Canada)			17.60	13.21		

PART II.

GENERAL REVIEW OF THE METAL TRACK QUESTION.

GENERAL REMARKS.

In this, as in all other questions, there are two extremes which are taken up from time to time. One of these is to the effect that the use of metal ties is merely a fad and an unsuccessful experiment; while the other is to the effect that metal ties are absolutely essential for a safe and substantial track. In July, 1892, a number of daily papers published statements to the effect that the Pennsylvania Railway was abandoning metal ties after experimenting with them for fifteen years, and sweeping conclusions were drawn, showing that metal ties as a whole were a complete failure. These conclusions were, of course, absurdly incorrect in view of the very limited trials on the Pennsylvania Railway and of the types of ties used in these trials, as previously noted, and in view, also, of the satisfactory results on many thousand miles of railway in other countries. The technical papers called attention to this baseless reasoning, and the following letter from Mr. B. E. Fernow (chief of the Forestry Division, Department of Agriculture) appeared in the Washington Post, setting forth the matter in its right light:

> In this morning's issue I observe a paragraph on the use of metal railway ties in this country, in which it is asserted that the Pennsylvania Railway Company has experimented with metal ties for fifteen years and finds them unsatisfactory.
>
> Since this matter is of more importance than it may at first appear, allow me to correct the impression which such a statement might produce in the minds of the public and uninformed railway engineers. Two years ago there was published from this division a report of over 350 pages, giving in greatest detail the experiments, not of the United States alone, but of the entire world, with reference to the use of metal for railway ties. It is there shown by actual statistics that over 25,000 miles of railway track of the world are laid on metal, and this kind of track has proved itself in most cases absolutely satisfactory and successful. In comparison with experiments of such magnitude, under all sorts of conditions, the alleged small trials of the few ties in the tracks of the Pennsylvania Railway Company are of no value whatsoever. To show the folly of generalizing from these few trials, allow me to say that in the report above referred to there are described 491 patents taken out in the United States alone, none of which is in actual use. There are, furthermore, described some 30 patents in actual use. It would, therefore, appear

that the system or patent used in the trials referred to would have to be stated in order to found an opinion, not on the efficiency of metal track, but on the efficiency of that patent.

In conclusion allow me to quote the resulting judgment from the reports of the chief engineers in control of nearly 25,000 miles of metal track, which I have worded as follows: "It is not a consideration of initial cost that makes the substitution of metal ties desirable or profitable. It is superiority of track, permanence of roadbed, safety, greatly reduced cost of maintenance, and hence ultimate saving and economy, that recommend the metal tie."

On the other hand, some enthusiasts claim that no track can be good and secure without metal ties, and that any form of metal tie is superior to a wooden tie, in which they are greatly mistaken; and such arguments tend to retard rather than hasten the introduction of metal track of proper design. In some cases these enthusiasts even advocate legislative action to compel the use of metal ties, oblivious of the fact that the efficient metal tie and the introduction of the same are matters of development and not of arbitrary action, as pointed out in my original report (*see* p. 294). One such letter sent to me, and printed in the Engineering News, New York, May 18, 1893, is given herewith, with comments:

SIR: To start with, let me say what most practical and scientific men well know that railway corporations are too conservative for their own good or the good of the public. This proposition could be illustrated in many ways. Cheap transportation is undoubtedly desired, and at once; but we must not overlook the question of remunerative profit to the parties who supply the money to accomplish this result. How can both these ends be attained? The reply is, by saving time—which is money. To save time, quicker speed must be made. This means improved facilities, such as machinery, roadbed, etc. It is not proposed here to consider the former, but to speak of the latter. It will be generally admitted that wooden ties, regardless of the character of the ballast used, are the cheapest as to first cost and the most expensive in the end. Iron ties are most expensive as regards first cost, but cheapest in the end, estimating for a period of ten years, so that corporations can not plead expense as a reason for not using iron ties, unless they think that a temporizing policy is best.

In saying this the particular form of iron tie is not considered. I am speaking of iron ties in general. It is well known that good, substantial iron ties are now obtainable at about three times the cost of good wooden ties. As to safety and solidity of roadbed made with iron ties there can be no question that it is far superior to that made with wooden ties. It is too well known by railway constructors to need verification, that the use of wooden ties necessitates the employment of spikes to hold the rails down, and that rails held by spikes do not remain in line, even with the most careful watching and driving. On curves, especially, it is a very unsafe method, because with the heavy trains now in use the spikes loosen and the rails spread. It is, in fact, a crude and dangerous method to use at even a moderate speed of train, and absolutely inexcusable where faster speed is used. The time has now arrived when the public will no longer tolerate such stupidity. They will not any longer call it conservatism or bad judgment, but criminal carelessness.

With iron ties of any known form the rails are securely held in line and firmly clamped to the ties, and no influence, whether that of speed of train or any other, can separate rail from tie. As far as these considerations go, no accident can occur to the train from spreading rails. The roadbed is absolutely safe under all conditions of train service. These facts being so, it is a great wonder that the traveling public do not rise up and demand of corporations that they abandon their penny-wise and pound-foolish plan and adopt the policy dictated by common sense and experience. The trouble does not lie with the railway superintendents, but with the railway directors, who hold the money bags and think more of speculating in the fluctuations of stocks than in affording safe conduct for man and beast.

The writer of this letter, who, it may be noted, had a few of his patented ties in use, was certainly going ahead much too fast in making such a sweeping demand for the introduction of metal ties, and their introduction is certainly not likely to be promoted very rapidly by a demand from the traveling public, which would be offset by a vigorous protest from stockholders. Such improvements are not introduced suddenly, but by a gradual growth and development, and in many cases there are other improvements which might well be made before the cost of metal ties is incurred. I fully recognize the advantages to be derived from the use of a well-designed metal track, and expect to see such track become more and more general, especially on main lines with exceptionally heavy traffic, in which case the economy in maintenance and renewals and in the stability of track outweigh the extra first cost. A very significant case of this kind is on the 4-track line between the Grand Central Station in New York and Mott Haven, where the New York Central and Hudson River Railway will lay 100-pound rails and steel ties, as already noted. There are, however, some important points, both technical and financial, which are overlooked in the above letter. While there are many cases on the busy lines of the rich companies where metal ties might well be introduced, there are many railways which could not afford the great increase in first cost, even for busy sections of line. But it does not therefore follow that the tracks of the latter railways will necessarily be unfit for high speed. With such improvements as preservative processes for wooden ties, steel tie-plates, improved fastenings, and other appliances, and a general better maintenance of track, a track can be made which will be perfectly safe under high speeds and heavy traffic, and which will be really more economical than the metal track, particularly if we compare the two for a period of ten years only, and remember at the same time that the cost of metal ties and reconstruction of track would be almost prohibitory in many cases. The writer of the letter referred to "iron" ties, but it may be taken for granted that he referred to steel, as far as this country is concerned.

Granting that spikes are inefficient fastenings under heavy and high-speed traffic, their use is not "necessitated" and it will be cheaper, and in general more economical, to use improved fastenings and adopt a higher standard of track maintenance than to reconstruct the track with metal ties. When such improvements as noted above have been made to track with wooden ties, special care should be taken to maintain the track in standard condition. Railway companies are certainly prone to be rather too conservative in their track work, but they are not philanthropic corporations and naturally wish to get along without very extensive expenditures, and it must be admitted that, as a rule, the real economy of large expenditures on improvements are not sufficiently recognized.

On the other hand, of the numerous forms of metal ties which have been tried in service, a comparatively small number has proved successful, and these are continually being improved upon. It is quite an unsustainable statement that "with iron ties of any known form, the rails are securely held in line and firmly clamped to the ties." The Pennsylvania Railway has had unsatisfactory results from its ties from their being inefficient, as pointed out in preceding paragraphs, and similar results have been obtained with many other forms of ties A poor and inefficient metal track is more expensive, both in first cost and maintenance, than a good track on wooden ties, and may be less safe under traffic. With regard to the fastenings of rails to metal ties, an endless variety of arrangements of bolts, clamps, rivets, and keys has been devised and tried, but only a few of them have proved satisfactory in service. Many of them are very complicated and therefore objectionable at once; others allow the rails to get loose and rattle, and in some cases spreading has occurred. On the other hand, there are sometimes indiscriminating statements made that metal track commonly has proved a failure, which, as above noted, is very far from being the truth.

What is wanted in metal track is a strong steel tie of ample weight and thickness, easy to manufacture and tamp, and of reasonable cost. With this must be fastenings that are simple and efficient, consisting of as few parts as possible. Such a track well laid and ballasted, and well looked after, will require little work for maintenance and few renewals, effecting economy, therefore, in its durability and in the reduction of track work, which it is so difficult to get properly done on lines with heavy traffic. This is the kind of track which we may reasonably hope to see introduced more and more rapidly. But what is wanted even more than this, particularly on lines with fast traffic, is a thorough improvement of existing track, with careful maintenance. To improve existing tracks in this way, and then steadily proceed with the introduction of metal track, as financial and traffic conditions warrant, will be the best and most satisfactory practice and will be equally to the benefit of the railway companies, the stockholders, and the traveling public in point of safety, economy, and convenience. As to the traveling public getting up and demanding metal ties, that would be a very foolish thing for the public to do, and, even assuming that its demand was heeded, harm rather than good would be the result to all concerned. Railways are improved by steady development and not by sudden ill-considered resolutions.

Between these extremes we have the varying results of practical experience to consider. Thus, while some roads report great satisfaction with their metal track others report dissatisfaction, and it is of the utmost importance to ascertain all the contributive causes for the results obtained. For instance, the abandonment of the further extension of metal track on the Netherlands State Railways may seem at first an example of the failure of such track until it is learned that the company operating the railway is only a lessee, and is therefore not interested in the carrying out of improvements, the benefits of which, not being realized for several years, may accrue to the owner (the State) instead of to the lessee (the company).

Taken altogether the detailed statements in the first part of this report, and the records of mileage of metal track, afford conclusive and incontrovertible evidence that metal track is far beyond an experimental stage, and is successful both in regard to its efficiency and economy. This is true not only of countries with moderate climate, durable wood for ties, and very heavy traffic, but also of pioneer light railways in countries where the climate is not favorable to the production of durable timber, and where insects and atmospheric influences are destructive to wooden ties. In this country, and still more so in Canada, railway officers are still very generally indifferent to the metal-track question, mainly through an objection to the necessary expenditures and to a failure to recognize the advantages or to realize the extent of experience in other countries.

The subject will be taken up by the International Railway Congress at its meeting in London in 1895. The conclusions presented at the meetings of 1885, 1887, and 1889 were given in the former report, and the subject was again taken up and actively discussed at the meeting in St. Petersburg, 1892, with the result that the following brief conclusion was arrived at:

> From the information presented it appears that metal ties, when placed under conditions suitable to the service (i. e., suitable to the traffic, ballast, etc.), can produce an economy in the expense of maintenance. It is therefore of interest to continue to gather the information given by the use of metal ties.

In the discussion several members considered that the speed of trains was a most important factor in regard to the efficiency of metal ties, and believed they were not suitable for high-speed traffic. Others, however, including Mr. Bricka, of the State railways of France, considered that suitable ties can be, and are, perfectly satisfactory with good traffic. I am certainly inclined to take the latter view, but it is of course necessary to have a strong tie, with secure attachments for the rail, as inefficient fastenings will soon loosen or give way under the severe vibration set up by trains passing at high speed. There seems to be little doubt that the best general type of tie is one of trough or channel form, with keyed or bolted clamp fastenings.

When introducing metal ties, one of the most important points is the selection of a good type and pattern; for although no harm can result from making experiments with different types, it is not advisable for any railway company to commit itself too far until it is reasonably certain that the tie chosen is suitable in every way for the duty it has to perform. Some of the worst defects in metal ties have not been discovered until after they have been in use for a year or more, under heavy traffic, and as very few of the large number of patents have emanated from practical track engineers, a little caution at first may save a great deal of money and time in the end. The Denham-Olpherts cast-iron tie, which is so largely used in India, is the result of the combined designs and patents of two engineers, who had exceptional facilities for studying the requirements of track; and yet the latest form of this tie is very different from the original pattern, proving plainly that the experience gained by actual practice is more to be depended upon than theory alone. The Post steel tie, which has given such good results in European and other countries, is also the invention of a very experienced and able engineer of permanent way; but the latest type of this tie is the outcome of many years' experience and patient observation, during which time the defects which existed in the earlier patterns have been eliminated. Some other remarks in this connection will be found on page 125.

To try metal ties in side tracks only is of little value; for no matter how heavy the traffic may be, the conditions as to speed, smoothness of track, etc., are not the same as on the main track, and therefore the test is inconclusive. A metal tie that will fail when laid where the speed seldom exceeds 10 miles per hour must be very faulty, and an experienced and unprejudiced track man would probably detect its defects without trying it in the track.

In regard to the possibility of steel-tie manufacture becoming an important industry in this country see the statement in following paragraphs on "Manufacture" and "Price."

In regard to the experimental introduction of steel ties in England and other countries where the railways have heavy traffic, the Indian Engineer suggests that there are thousands of miles of sidings and branch lines where the traffic is heavy, although the speed never exceeds 20 miles per hour, and on such lines there would not be any danger in making experiments with different patterns of metal ties. If this were done, the workmen, as well as the supervising staff, would gradually become accustomed to this class of material, and at the same time obtain experience and observations which would be invaluable when it became necessary to extend the system to the main tracks. At the same time it must be pointed out that trial sections of less than half a mile in length are of no practical value, and that, unless all the conditions are carefully watched and the results recorded by unprejudiced men, the statistics obtained will not be worth the paper they are written on.

The paper also stated that almost any type of metal tie would outlast three of the best wooden ties when placed in a siding or in any place where the speed is low and correct gauge almost the only requisite; and also that the experience obtained with metal ties in India and elsewhere proves conclusively that when properly designed and laid they are able to stand the heaviest traffic and highest speed that is possible with the locomotives now in use. By using metal ties in sidings alone a large reduction in the maintenance charges of English railways would be possible; and if the prices of wooden ties were not lowered by strictly following this course, it would, at any rate, prevent a rise in price, as it has already done in India.

Mr. B. E. Fernow, in Bulletin No. 1 of the Forestry Division, U. S. Department of Agriculture, 1887, made the following remarks:

From the experience so far accumulated it is claimed that the requirements of a good tie can be fulfilled by the steel ties now made, namely: (1) Appropriate form. (2) A section with sufficient moment of resistance. (3) A material not easily fractured. (4) Sufficient bearing area and length to resist lateral, longitudinal, and vertical strains.

To which may be added the following:

(1) The average life of good steel ties is considerably longer than that of best wooden ties (estimated at 30 to 50 years). [*See* "Efficiency and Durability."—E. E. R. T.]

(2) The width of gauge is better maintained with steel ties.

(3) Cost of maintenance of permanent road with steel ties remains almost constant after the second year, while with wooden ties it increases constantly with age, making the average cost greater than with the former.

(4) Rail fastenings are possible with steel ties which are at once safer and more easily maintained than those for wooden ties.

(5) A good steel tie should not cost more than from 125 to 150 per cent of the cost of wooden ties.

(6) The "old material" value of a steel tie is greater than that of a wooden sleeper.

"If, for comparison of the relative cost per mile of steel and wood, account is taken of the manufacture, transport, laying, maintenance, interest, and value of scrap, it is seen that there are few countries in the world where the exclusive use of wood ties is really economical. For countries where climate and insects destroy wood sleepers in a few years this is evident; but it speaks still better for steel sleepers that in Holland, which produces no steel and gets wood sleepers very cheaply by sea, all the railway companies have introduced metal sleepers without any pressure from the Government."

TYPES OF TRACK.

(1) *Cross-ties.*—By far the largest proportion of the mileage of metal track is laid with cross ties, and this has proved to be the most satisfactory type under conditions of climate and service similar to those which obtain in this country, while it has the advantages of simplicity in construction and ease of renewal. As the whole of Part II, with the exception of the following paragraphs on "Longitudinals" and "Bowls and Plates," refers to this type of construction, it is not necessary to discuss it specially at this point.

(2) *Longitudinals.*—This system has proved to be in general inefficient and troublesome, though its use is still regarded with favor on the Northwestern Railway (Austria), but most of the German railways which have tried this type of track have abandoned it after sufficiently long experience to thoroughly compare it with the cross-tie system. One of the principal defects was the wear between the rail and longitudinal, not only at the joints, but all along the continuous bearing.

This was due to the insufficient strength and resistance of the track, leading to an excessive deflection or wave motion under trains, and this wear was aggravated by the use of light rails, the wave motion of which was not the same as that of the longitudinal, although one of the claims made for this system has been that lighter rails could be successfully used with the continuous bearings of longitudinals than with the intermittent bearings of cross ties. Another weakness was that the joints could not be spliced in such a way as to make them as stiff as the rail between joints, while with cross ties the ties may be placed closer together at the joints. Several patents on such tracks have been taken out in this country, as shown in the summary of Appendix 2.

As pointed out by Mr. Cantagrel, a French engineer (whose paper on metal track was translated by me in 1887), a track carried on longitudinals should, theoretically, be preferable in many ways to track carried on cross-ties, for the following reasons, among others:

The rail having a continuous support, all shocks are eliminated, and there should consequently be an economy in the cost of maintenance of track and a diminution in the wear of the rolling stock. The adoption of longitudinals ought also to give an economy in first cost from the fact that the length of longitudinals for 1 yard of track is about 2 yards, while with cross-ties it is difficult to reduce the length below 2½ yards. To this important question of economy should be added that the weight per yard of a rail having a continuous support may be safely diminished; finally the moment of inertia of the rail and longitudinal jointly is greater than that of the rail, even when strengthened with regard to its vertical or horizontal axis. All these advantages are more apparent than real; experience has enabled them to be judged upon and has brought out numerous drawbacks which had not been foreseen. The estimated economy in first cost is found to be considerably reduced by the necessity of employing gauge rods strong enough to tie the track firmly together and to give the rail the desired cant. In spite of the strength of the transverse bars employed, it is very difficult to insure perfect accuracy in the track by these means. In the Hilf system it was attempted to obviate this drawback by introducing cross-ties of the same section as the longitudinal under the joints of the rails and longitudinals, but then the joints were found to be too rigid with regard to the general elasticity of the track, which sagged between the joints, occasioning at the middle of the span deflections of 0.36 inch to 0.48 inch during the passage of trains. To reduce the rigidity of the joints, these cross-ties were replaced by others of T or L iron. The distortions of level were thereby reduced, but the economical advantage of longitudinals disappeared. The rail is not really supported for its entire length, owing to the uneven ballasting under the longitudinal. This condition not being absolutely fulfilled, it would soon be necessary to return to the use of heavy rails.

The wear of rolling stock is certainly less with metal longitudinals than with wooden cross-ties, but the economy due to this is proved to be reduced by the effect of the uneven motion occasioned on tracks with longitudinals by the slight rigidity of the cross-tie connections. Nevertheless, regular observations made in Germany showed that the tires of engines running only over longitudinal systems of track were worn only one-third as much as those of engines running only on tracks with cross-ties.

Track on longitudinals, while easy to lay on tangents, requires considerable care and attention for laying on curves. It is necessary then to bend the longitudinal to the required radius (an operation that can only be done while the metal is hot, and that requires special plant) or to have special apparatus for drilling the holes for the rail attachments for each radius of curve adopted. Herein is a serious drawback. Either a special, costly, and cumbrous plant must be maintained, or it may be necessary to have in each storage depot a large number of longitudinals for each radius of curve existing on the line. The regular maintenance of the track is difficult; it requires an even ballasting which must be constantly attended to, for it does not keep in order. Besides, when it becomes necessary to replace a broken or damaged rail or longitudinal serious difficulties are experienced owing to the necessity of making the change between the passage of trains, which is especially difficult if the joints of the rails and longitudinals do not correspond. The longitudinal system, owing to the weakness of the transverse connections, has a tendency to cause derailment; the track spreads, the rail shifts, and when a thaw happens, and the track is least stable, the derailment occurs. These accidents are always more serious than with cross-ties. In fact, however strong the tie-rods or tiebars may be, they have not sufficient strength to bear the load on an axle. They bend, therefore, and, drawing the two lines of rails together, help to increase the distortion of the track.

Experience has also shown the absolute necessity for the good condition of track on the longitudinal system, of a perfect drainage of the roadbed; water must not be allowed to lie in the ballast, as it has a tendency, especially on grades, to follow the lines of the longitudinals, and thus to help to destroy that regularity of the ballasting which is so necessary. In Germany special arrangements have been made for draining tracks on this system. On the Alsace-Lorraine railways, which employed the Hartwich track, each line of rails is placed on a longitudinal rubble drain. Every 16.4 feet these drains are connected by a cross drain running into a lateral ditch, as shown in Fig. 6, Appendix 1. Such drainage works largely increase the first cost of tracks laid on longitudinal ties.

On the Baden State railways (Germany) the longitudinals are being replaced with cross-ties, the former having been found unsatisfactory in the maintenance of exact gauge and in the drainage of the track. The use of longitudinals has also been abandoned on the Elberfeld division of the Prussian State railways and on the Belgian State railways. The Metropolitan Railway of Berlin (Stadtbahn), on the Berlin division of the Prussian State railways, adopted metal longitudinals, with the expectation of reducing the noise of trains passing on the masonry viaduct of its elevated line, but after six years of comparatively heavy traffic they were abandoned for wooden cross-ties on account of the insufficient support across the track for bearing surface and for resistance to lateral strains on the track, which made it difficult to maintain gauge and alignment. The fact that this type has been seriously proposed as an improved type of first-class track for this country warrants a somewhat extended presentation and discussion of the subject.

In a paper on "The advantages of a longitudinal bearing system for railway tracks" (Transactions of the American Society of Civil Engineers, August, 1891), Mr. Thomas C. Clarke claimed that the cross-tie system was becoming insufficient for the heavy traffic and wheel loads of American railways, and that some change was necessary. He referred to the ever-present difficulty of the rail joints and to the inefficiency of spike fastenings, while steel cross-ties he considered to be deficient in stiffness (as no doubt some of them are) and to afford no improvement at the joints, so that the ties work loose in the ballast (practical experience in other countries—on the State railways of France, for instance—does not corroborate this statement), and for these reasons, he said, it is difficult to keep a metal cross-tie system in good line and level. He considered that the only radical cure of the difficulty was to return to the old continuous-bearing system, improved to avoid the defects found in the old system. Mr. Clarke presented his views on the longitudinal system as follows:

The only way, in the author's belief, to absolutely prevent low joints is to place continuous-bearing pieces under the whole length of the rails and breaking joint with them. The solid part of the bearer supports the joint of the rail and the solid part of the rail bridges over the joint of the bearer, and, what is of the highest significance, a small amount of longitudinal movement or play between the upper and lower members will not cause deflection when arranged as described. The requisites of a properly designed longitudinal system are as follows:

1. The longitudinal under the rail must be stiff enough to transmit the load to such a distance, on each side of the wheel, as will limit the pressure to not much over 2 tons per square foot of bearing surface, without requiring excessive width. Experience has shown that a greater pressure than 2 tons per square foot will sink ties too deep into the gravel or broken stone.

2. The next thing is to attach the rails and longitudinal bearers together by a form of fastening strong enough to resist all strains and shocks and yet allow of freedom of the rail to expand and contract, independently of its bearer. It must also be held to its bearer, so that creeping of the rail on the bearer may be prevented, and that without any notching or cutting of the rail that will impair its strength. The rails must break joint with the bearers. The fastenings must be so made that the rails can be quickly removed and replaced by new ones without disturbing the bearers. The fastenings must be able to hold for a time a broken rail, so that it will safely pass the trains, and no system but the longitudinal can do this.

3. The bearers (and rails) should be united firmly together by light metallic gauge ties, placed near enough to properly preserve the accuracy of the gauge.

4. The bearers and gauge ties should be of such shapes as can be easily tamped with gravel or broken stone; as will stay in place vertically, laterally, and longitudinally, and will allow of drainage to pass between them.

5. The system should be so planned that no difficulty of construction can occur at curves, either in alinement or elevation of outer rail. Also, it should be so made as to easily join to the ordinary form of T-rail at turnouts and switches.

6. Besides the obvious advantages which such a construction gives, there are two others: The upper rail can be made of a harder and better-worked steel, while the bearer can be made of a softer and tougher quality of metal. Probably basic steel would do for this.

Owing to the rails being supported under their entire length by continuous bearers, they can be made of less depth and sectional area in their lower flanges than at present. The metal so saved can be put into the head of the rail, where it is most needed. (As a matter of fact, lighter rails cause greater wear of the longitudinals, as on the Hesse Louis Railway, Germany.—E. E. R. T.) It is believed that rails can be designed for a longitudinal system with heads 3 inches wide, and they need not weigh over 70 pounds to the yard. * * * There are two defects in the Hohenegger design of track. Mr. Hohenegger says that the ballast, which consists of broken stone and river gravel, is compressed by tamping and the pressure of passing trains, to such an extent that it can only be loosened with a pick. This compression extends a foot below the longitudinal and prevents the quick drainage of water from between the rails. This could have been prevented by a better section of bearer, possibly of a T-shape. The ballast could then be tamped against the vertical member from both sides and there being nothing to confine it there, the packing would not have taken place. Another mistake was to make the joints of the rails and of the longitudinal bearers coincide, instead of breaking-joints. Mr. Hohenegger says nothing about the existence of low or battered joints, but they must have existed, and breaking joints with the bearers would have prevented them.

As to the proposed T-section of longitudinal, reference to my former report and to the statement respecting the Northwestern Railway of Austria will show that such sections have been tried and found unsatisfactory. In the discussion of this paper it was pointed out that the track proposed by Mr. Clarke (the Hohenegger track) was very inadequate in stiffness and bearing surface, the latter being only 30 square feet per rail, as against 48 square feet with cross ties, and with that limited bearing surface there would probably be serious rolling of the train, owing to the difficulty of making the ballast equally firm under each rail. Difficulties of drainage, raising track in surfacing, shimming, etc., were also referred to.

In a paper on "Longitudinals *v.* Cross-Ties for Railway Track" (Transactions of the American Society of Civil Engineers, December, 1891). I discussed the question generally, both in regard to wooden and metal ties and longitudinals, and pointed out also that timber longitudinals are largely used on European railway bridges, and to some extent in large railway terminal stations in this country, including the Louisville and Nashville Railway station at Louisville, Ky., and the Pennsylvania Railway station at Broad street, Philadelphia. The conditions there, however, are very different from those on the ordinary open track. In the discussion reference was made to possible combinations of the longitudinal and cross-tie systems, and the possibility of effecting material saving in maintenance and renewals by adopting a more expensive and substantial system of track than that now generally employed. The following is an extract from my paper:

> In regard to metal longitudinals, the most extensive experiments with these has been in Germany and Austria; but while the use of metal cross-ties is being extended considerably, the longitudinals are only used to a limited extent on new work, and in some places they are being abandoned. The transverse connections generally give some trouble, especially at curves, and the general construction of the roadbed and the work of track-laying require more care and labor, while the cost of maintenance has in some cases been found to be higher with longitudinal than with cross-ties. There has also been difficulty in maintaining the gauge. A German authority stated in an article in a technical magazine, in 1886, that with longitudinals of metal it is undesirable to have many transverse connections, as they will counteract the advantages of the longitudinals and introduce some of the disadvantages of the cross-ties. He recommended a connection at the ends of the longitudinals, and also at the middle if more were considered necessary.
>
> The continuous bearing is theoretically the better, giving a uniform transmission of the wave motion under rolling loads, with a consequent smoother rolling and less wear. The separate bearings of cross-ties exert a disturbing influence on this wave motion, causing uneven wear, but it is possible to obtain sufficiently satisfactory results in practice in this respect from the cross-tie system. The continuous bearing gives a better resistance to lateral strains on the rails, but with cross-ties this can be provided for by the use of tie plates. The quantity of ballast is about the same, but there is difficulty in draining it when longitudinals are used. Renewals are probably cheaper with cross-ties. After considering the various points he came to the conclusion that the cross-tie system will continue to be the standard. The same conclusion was also arrived at by a convention of the German Railway Union a few years ago.

Mr. Clarke, in his paper (previously quoted from), does not seem to have done his subject justice in merely quoting the statements of Mr. Hohenegger concerning the latter's system of track on the Northwestern Railway, Austria, of which he is chief engineer. In my report to the U. S. Department of Agriculture upon "The substitution of metal for wood for railway ties" (1890), there are many other statements concerning metal longitudinals and the experience therewith, which show different views from those entertained by Mr. Hohenegger. A longitudinal system would require more care and more skilled labor in laying and maintenance than it is now usual to find on any but the first-class lines in this country, and the work would be especially complicated at frogs and switches and on sharp curves. A defect of this system of track is the very much smaller area of bearing surface upon the ballast as compared with that of the cross-tie system, and, as already stated, it is not considered desirable to increase the number of transverse connections. This, added to the increased difficulty in tamping and other features, would tend to add largely to the maintenance expenses by continual work in keeping the track up to surface. Under heavy traffic it would probably not be found advisable to make any great reduction in the weight of the rail. For existing roads adopting this system the entire reconstruction of the track would be a difficult and costly work, especially upon lines with heavy traffic, and it is a question whether the efficiency and economy resulting from the new track would be sufficient to warrant the change. It is only upon lines with heavy traffic that the introduction of the longitudinal system of track is likely to be considered, even if its advantages are proved; but the traffic upon the lines mentioned by Mr. Clarke is comparatively light.

On the whole, it appears probable that the cost of a system of track with longitudinals, fitted for heavy traffic, would be considerably in excess of the cost of a track with cross-ties of equal strength and efficiency. It is true that some engineers are in favor of the longitudinal system, theoretically at least, and it is possible that it may constitute the track of the railway of the future; but its introduction does not seem probable, and the most important work now to be done is to provide for the improvement of the efficiency of the present system of track. These remarks apply to the track in general, but there may be special cases, as at bridges, etc., where the use of longitudinal bearings may be advantageous.

Granting that much of the existing track is defective, the author does not think there is room for claiming that (as stated in Mr. Clarke's paper) the system of track is giving out at all points, for the existing tracks are capable of very great improvement, without departing from the present general system of construction. The author recognizes the advantages of the longitudinal system, as has already been shown; but its general introduction on the ordinary open track does not seem probable, and under such ordinary conditions of track and traffic it is likely that the present system of track, with cross-ties, can be very much improved at less cost than would be involved in the introduction of a new system.

The principle of the Haarmann self-bearing or girder rail (*see* "Germany," and Pl. 2) is very different from that of the ordinary system, where ordinary rails are attached to separate longitudinals, and the Haarmann track is meeting with favor in Germany, where the ordinary system of longitudinal construction has been practically abandoned. In this connection, however, it is curious to note that deep T-rails tried in Germany many years ago were abandoned, as they made a very hard riding track.

(3) *Bowls and plates.*—The use of ties composed of a pair of bowls or plates (usually of cast iron) connected by a tie-rod or tiebar is now almost confined to India and South America, but there they continue to be extensively used, and the most recent patterns in India are said to

be very satisfactory, while breakages are remarkably rare. It is quite improbable, however, that any such system will be introduced into this country. Care is required in tamping them so as to give a uniformly firm bearing to the two bowls or plates, as otherwise the track will get out of surface, causing considerable rolling motion of the cars, and perhaps leading to a dangerous widening of the gauge. The modern track with plate ties of the East Indian Railway, as laid on the Delhi, Umballa and Kalka Railway, costs about $6,853 per mile for material, or $11,322 including freight, hauling, and laying.

In Mr. Cantagrel's paper, already referred to, it is stated that Mr. James Livesey first introduced the method of introducing plate ties ("pot sleepers") for supporting railway tracks, and, though little used in Europe, they have met with much favor abroad, especially in India. This favor is principally because these separate ties give good results, the conditions of speed and the weight of the trains being very different in the colonies to what they are in Europe; and they offer this advantage, for transport from England to India, that two of these ties weigh less than one cross-tie. In the first designs Mr. Livesey placed the rail directly on the support. Afterwards he deemed it preferable to substitute a more elastic track, and therefore interposed a bearing piece of wood, or rubber, or springs; but the difficulty of maintenance, owing to this elasticity, soon caused him to abandon these additions and to return to a slightly modified form of the original type.

The Livesey supports (*see* Pl. XX and also fig. 16 in appendix) are made of sheet steel. A cheek riveted to the support serves to receive the flange of the rail; the other side of the flange is held in place by a clamp tightened by a bolt. The loose pieces are thus reduced to a minimum.

Requirements and comparison of different systems of superstructure.—(B. E. Fernow, in Bulletin No. 1, Division of Forestry, U. S. Department of Agriculture, 1887)—

A very elaborate investigation into the merits of different systems of track superstructure, with wooden and metallic longitudinal or cross-ties, has been published in the "Organ für Fortschritte des Eisenbahnwesens" for 1886, by a high authority, W. Fuchs, replete with mathematical demonstrations and presenting a most thorough discussion on theoretical grounds, the results of which are given in the following notes:

A.—*The aggressive forces against which any system of superstructure must be prepared to stand, are*—

a) Vertical: pressure at the wheel, usually and properly taken as 7,000 kilograms (15,400 pounds).

(b) Lateral: shocks representing a total effect of 5.5 tons, discounted by a relief of 2 tons from the opposite wheel, the total pressure being roughly 5,000 kilograms, which may increase to the maximum 8,000 kilograms (11,000 to 17,600 pounds).

(c) Longitudinal: per rail not over 5,025 kilograms, adhesive weight of locomotive taken as 42,000 kilograms.

B.—*Requirements of systems.*

(*a*) Longitudinals.

The manner, shape, and number of cross connections seem to be of utmost importance; blade-shaped connections are preferable to those with broad surface on account of the tendency of the latter to form humps in the roadbed; a number of cross connections is undesirable as counteracting the advantages of the long tie and introducing the faults of the cross-tie system; the connection is best made at the rail joint, by which the favorable influence of such connection is utilized. If more connections are required, they are best applied in the middle, at equal distances from the ends of the tie. The main difficulty of long-tie systems lies in their deficient drainage, two "backs" forming alongside the tie in the roadbed. This objection is increased when the cross connection has a flat surface.

Of all long-tie systems Haarmann's (employed on Berlin City Railway) [now abandoned—E. E. R. T.] appears best, exception being taken only to the form of cross connection. Hilf's system is found in all points inferior, the former showing all the advantages required for an elegant and simply constructed superstructure; the only objection to it is that to which all long-tie systems are open—deficient drainage.

(*b*) Cross-ties.

The parts of the rail lying between the support and a point halfway between supports receive less wear, and an uneven use of the rail is the consequence. Connections of rails to ties can never be made too rigid. The foot of the rail should preferably not be supported in its entire breadth, but only on its flanges to a sufficient breadth, thereby insuring more stability, permitting the use of rails not having a perfectly smooth foot, and avoiding an extra demand of resistance against tilting on the part of fastenings.

Bedplates are most desirable for wooden as well as metal cross-ties, making the manufacture of the latter ties less expensive and less difficult. By the use of bedplates the eating into parts most used, and the consequences resulting therefrom on all parts of the superstructure, can be avoided. The best mode of fastening is presented by bedplates with hook bolts.

The best length for metal cross-ties is given as 227.7 centimeters (7 feet 5½ inches); and in order to diminish the strain on the tie and counteract the tendency of every cross-tie system to change the gauge in consequence of a bending of the tie, there should be no tamping underneath for a length of 52.7 centimeters (20.7 inches). A trough, open only on the lower side, divided into three compartments by two cross ribs placed 26.35 centimeters (10.3 inches) from the center of the tie, the outer parts filled with bed material, the central part empty, will answer to this requirement. At 10 centimeters (3.93 inches, the height of a cross-tie), a metal cross-tie system furnishes, even in the most unfavorable bed materal, at least 1.33 times greater resistance to side strains than a wooden superstructure.

The distance of ties, at 1 meter (3.28 feet), used on the Prussian profile, the author considers too great and 0.95 meter (3.12 feet), or even less on curves, just permissible. Against longitudinal forces the transmission of the shock from the rail to the tie is more imperfect with metal systems than with wooden ties; yet the resistance of a good metal system to displacement in the direction of the track is very much greater than with wooden ties. Iron ties of 10 centimeters (10.3 inches) height withstand the effects of longitudinal forces.

The cross-tie with short steps leaning somewhat outward is the most perfect.

The need of bedding material is smaller than in any other superstructure.

Bed-plates with bolts offer very firm connections and can be easily moved or replaced. Changes of gauge can be as easily and accurately effected as with other connections. The mode of fastening is independent of the form of tie, and can be applied to any iron tie at any later time.

The weight per running foot ought to be somewhat greater than that of ties now used, but the greater weight refers to such parts as are little subject to wear, and it does not exceed that required in the long-tie system.

C.—*Comparison of wood and metal superstructures.*

The superiority of well-devised metal superstructures over those with timber ties as usually applied is more clear if we consider the more or less secure mode of fastenings in both systems.

If the greatest side strain of 7,350 kilograms (16,000 pounds) be exerted on the rail just over the tie, and if two spikes are used outside and one inside for fastening, then if the coefficient of friction between metal and wood be $u = \frac{1}{2}$, the two outside spikes must offer resistance $R = 7{,}350 - \frac{6000}{2} = 4{,}350$ kilograms (9,570 pounds), while under usual conditions they can not offer more than 3,200 kilograms (7,040 pounds); one shock, therefore, is capable of loosening the rail here. Only when the three spikes are united by bedplates does their resistance grow to 4,800 kilograms (10,560 pounds), or their total combined resistance to $4{,}800 + 3{,}000 = 7{,}800$ kilograms (17,160 pounds), against a strain of 7,350 (16,000 pounds). But this resistance is found only in absolutely sound ties. Still less secure is the usual mode of fastening against tilting; for the inside spike can not offer more than 2,050 kilograms' (4,510 pounds) resistance, while the attacking force may reach a maximum of 4,860 kilograms (10,692 pounds).

D.—*Comparison of longitudinal and cross-tie systems.*

The former, if perfect, like all superstructures with single supports, is superior in regard to an even uniform transmission of the force waves which form under the moving loads. The many supports of a cross-tie system exert a disturbing influence on this wave movement, in consequence of which the rail is not uniformly utilized. Therefore in any cross-tie system rails must wear unevenly.

It follows that on longitudinal systems smoother rolling of cars and less wear of all parts must result than on cross-ties; yet it is possible to get sufficient satisfaction in this respect from the latter system.

Of more importance is the greater security of longitudinal than cross-tie systems against side strains and consequent breakage of rails.

By use of bedplates on each tie or enlargement of rail foot this objection can be overcome.

In regard to drainage no satisfaction has as yet been obtained in the longitudinal systems. The quantity of bed material needed amounts to the same in both systems. Replacement is probably cheaper with cross-ties. Metal weight is alike, yet in longitudinal the wearing parts are the lightest.

The author concludes that, as only two points are in favor of the long-tie system, which can partly be attained in cross-tie systems, the latter will remain the standard.

MATERIAL.

Cross-ties are usually of mild steel, though in Belgium wrought iron is in some cases preferred. The analysis of the steel for the pressed steel ties of the New York Central Railway (as furnished by the manufacturers, the Schoen Manufacturing Company, of Pittsburg, Pa.) is as follows:

	Per cent.
Carbon	0.10
Manganese	.40
Phosphorous	.081
Sulphur	.033

The low carbon percentage or "softness" is said to be necessary for metal to stand the hydraulic press or drop forge shaping, but some

experts in steel and rail manufacture and use consider it too low. The tensile strength would be about 50,000 to 55,000 pounds per square inch. The Hunt ties for light industrial railways are of soft steel, of 32,000 pounds tensile strength. The following table gives the grades of metal of ties reported upon at the International Railway Congress of 1892:

Country.	Railway.	Type of tie.	Metal of tie.	Resistance (pounds per square millimeter).	Minimum elongation.	Reduction of area.
					Per cent.	*Per cent.*
France	State	3 types. (*See* part 1.)	Mild steel	99	15	35
	Western	Channel	Steel	121 to 132	21 to 25½ in 8 ins.	....
Holland	Netherlands State.	Post's	do	99	....	35
Belgium	Great Central	Trough	Iron	No tests specified, the makers guaranteeing ties for 5 years.		
Switzerland	Gotthard	do	Steel	5 to 5½ tons per sq. cm.	18 to 22 in 8 ins.	....
	Jura Simplon	....	....	83.6 to 105.6	....	....
Denmark	State	Trough	Martin steel	....	....	....
Algeria	Algerian (Paris, Lyons and Mediterranean Railway).	Hilf	Steel and iron	99	18	....
	Bone-Guelma	Boyen.-Pons.	Steel	105.6	22	....
	do	Severac	do	88	20	....

The following is an extract from a paper by Mr. H. K. Bamber (Proceedings of the Institution of Civil Engineers, 1892), on "The manufacture of transverse steel sleepers," in which he refers to the types of ties having pressed lugs to hold the rail base (*see also* "Manufacture of metal ties," further on):

> The quality of the steel to be used in the manufacture of sleepers whose rail fastenings are formed out of, and are in a piece with, the sleeper itself, is of the utmost importance, and steel-makers have had to study this matter very carefully. The special requirements of sleeper steel at present are as follows: (1) That it shall be as even as possible in quality. (2) That it shall withstand an ultimate tensile stress of at most from 26 to 21 tons per square inch. (3) That it shall elongate at least 20 per cent in a length of 10 inches. (4) That it shall show a contraction of area at point of fracture of not less than 40 per cent. (5) That it shall be capable of being bent double on itself to an inside radius of one-half its mean thickness without sign of crack or fracture.
>
> The steel used is made by the Bessemer, Thomas, and Siemens-Martin processes, and possesses the qualities of homogeneity, malleability, and ductility. The first of these qualities depends largely on the proper mixing of the steel, effected either by means of a mechanical stirrer, which is lowered into the ladle containing the metal which has just been run from the converter, and made to revolve at about 100 revolutions per minute, or by blowing the metal at such a temperature as to permit of its being poured from the converter into an intermediate ladle, thence into the casting-pit ladle, and finally into the ingot molds, in a sufficiently fluid condition, which can only be done when pig iron sufficiently high in silicon is used. The object of this mixing is to insure sufficient and uniform distribution throughout the iron of the manganese which has been run into the blown metal to permit the escape of occluded gases, and to insure the tranquillity of the metal after being poured into the ingot molds.
>
> There seems to be no doubt that want of sufficient mixing is the reason why, sometimes, in a dozen sleepers cut from one length of rolled plate, all having been punched

with equal care, some of the clips fail under the bending test before reaching an angle of 90°, while others can be bent double and hammered down on the back of the sleeper without fracture. It has been the author's experience that this want of regularity of quality is greatest when the metal, after the addition of the manganese, is perhaps blown again for a few seconds, and not afterwards mechanically mixed by either of the two methods above mentioned.

The analyses of the class of steel used by the five chief sleeper makers in the kingdom, and the results of tensile tests showing the quality and range of each, are given below. The analysis in each case corresponds with the "medium" quality of the steel given under each number, and the tensile tests which were made during the execution of orders represent hundreds of thousands of tons of steel. It will be understood that the terms "soft," "medium," "hard," are used relatively, for the purpose of showing the range and averages of the different steels.

In order to show that steel of a higher tensile strength than 31 tons is not suitable for use in the manufacture of these sleepers, the author gives the analyses and the results of tensile tests of steel taken from the backs or thickest parts of some sleepers which had broken in two by falling on a hard substance when being discharged from railway wagons. They were all made under one order.

Analysis of "medium" steel, acid manufacture.

	Number—				
	1.	2.	3.	4.	5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Carbon	0.13	0.12	0.12	0.09	0.11
Silicon	.03	.01	.02	nil.	.02
Sulphur	.06	.06	.05	.05	.05
Phosphorus	.06	.06	.05	.06	.05
Manganese	.40	.40	.70	.42	.75

Results of the tensile tests of these steels.

	Quality.									
	Medium.					Hard.				
	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.
Load per square inch..tons..	30.41	27.38	27.31	28.30	29.90	32.50	28.73	29.63	29.30	33.70
Elongation in 10 inches, per cent	23	26.50	21.56	21.50	23	22.65	25	22.30	23	22.50
Contraction ......per cent..	46	56	......	......	48	39.08	59.50	......	......	46

Analyses of steel of broken ties.

	a.	*b.*	*c.*	*d.*	*e.*
Carbon	0.15	0.15	0.15	0.14	0.15
Silicon	.05	.04	.05	.05	.05
Sulphur	.06	.06	.058	.055	.06
Phosphorus	.08	.08	.083	.08	.08
Manganese	.46	.47	.45	.47	9.49
Tensile test pieces, unannealed:					
Load per square inch	39.60	36	37	36.66	34
Elongation in 8 inches ......per cent..	nil.	13.67	14.22	14.45	2.74
Contraction ......do....	nil.	42	38	40	nil.
Tensile test pieces. annealed:					
Load per square inch	32.50	32.50	32.50	33.33	32.50
Elongation in 8 inches ......per cent..	21.09	23.83	30.31	23.44	23.84
Contraction ......do....	48	48	52	42	46

It would appear as though the four sleepers *a*, *b*, *c*, and *e* had been made from one rolled bar. It was evident that these five sleepers had been made from plates which had been "cold rolled," that is, they were not at a proper heat at the time of rolling, either from neglect at the furnace, or through some delay after reaching the roughing rolls. The subsequent punching up of the clips at too low a heat had developed strains, starting at an angle of 45° with the root of the clip, along which lines of strain the sleeper ultimately broke.

The lesson to be learnt from these experiments seems to be that steel having a tensional strength of 32.25 tons per square inch is not suitable for use in the manufacture of sleepers which have to withstand strains caused by the punching up of portions of the plate, because by working the steel at too low a heat strains may be set up by the subsequent operation of punching to such an extent as to cause fracture as in the cases just considered. It is the author's experience that, if in the ordinary course of manufacture, the steel be kept at about 23 tons tensile strength per square inch, the clips may be bent double without any fear of fracture taking place; but when of such tensile strength as to withstand 31 tons per square inch, at least 4 per cent of the clips will fail on being bent to an angle of 90°. He is, therefore, of opinion that steel used in the manufacture of sleepers of this type should be allowed to range between 26 and 30 tons, and he finds that the steel which gives in all respects the most satisfactory results is that which answers to the following analysis and tests:

Analysis.

	Per cent.
Carbon	0.12
Silicon	.02
Sulphur	05
Phosphorus	.05
Manganese	.70

Tensional strength.

Load per square inch	tons..	28
Elongation in 10 inches	per cent..	24
Contraction	do....	50

The steel should be capable of being bent double on itself to an inside radius of one-half its mean thickness without sign of lamination, crack, or fracture.

In regard to the use of steel and cast-iron ties in India, it is stated that unserviceable steel ties have little or no value as scrap, while cast-iron scrap is in great demand.

MANUFACTURE OF METAL TIES.

Steel cross-ties are usually either rolled from ingots, like rails, or pressed to shape by hydraulic presses from flat plates, and the latter method is that employed for most of the ties which have been tried in this country. Where holes are to be punched or drilled they should be made simultaneously, as it has been found that where the holes at one end of a tie are made first sufficient care is not taken to get the others at the mathematically exact point, so that exact uniformity of gauge is not assured. Drilled holes are generally preferable, and punched holes should be either round or have rounded corners, as cracks are almost certain to start from sharp-cornered holes. The manufacture should also be under the supervision of an inspector representing the railway company. Machining and hand finishing are to be avoided as far as possible; but Mr. Price, whose tie is being tried on the Philadelphia and Reading Railway, makes the special claim that any railway company can buy the material and manufacture the Price tie at its own shops, using the ordinary drilling and riveting appliances.

An engineer, in writing about the experiences with metal ties on Indian railways, states that one of the most frequent complaints made against such ties is the variation in gauge of track; but when this occurs it is due mainly to the carelessness of the workmen engaged in their manufacture, for there is no reason why the gauge should not be exact if proper care is taken to use proper tools, and to change the punches, etc., directly they show any signs of being blunt or worn. Indian experience goes to prove that the workmen do not change the punches sufficiently often to insure first-class work, unless they are compelled to do so; but if the material is carefully inspected before being accepted, and all that is not correct rejected, they can soon be made to understand that it will not pay to turn out inferior work.

Railway companies which purchase metal ties should have all the material, including the fittings, examined at the works by a competent inspector having power to reject unsatisfactory work, and even when made in the company's own workshops it should be inspected by a representative of the track department before being used. A smart nspector, supplied with steel templets and gauges, can, with the help of two laborers, examine a large quantity of material in a day, and it is labor well spent. The inspector should be familiar with practical track work as well as with the manufacture. In addition to gauging the parts separately, it is usual in foreign ironworks where large orders are being turned out to fit up a pair of 30-foot steel rails from each day's make, as the gauge, proper amount of inward cant for the rail, etc., can be tested more correctly where 12 to 16 ties are connected than if they were tried singly.

When tie-bars, or ties themselves, have to be punched at both ends, the full number of holes should be punched at one stroke of the machine, as these holes determine the gauge, and once the machine is set correctly and properly secured, no error is possible so long as the tools are in good order, besides which this arrangement is more economical.

To show the importance of gauging each part separately the writer above referred to mentions that when Denham-Olpherts' cast-iron ties have been made up with parts received from different manufacturers, there has been nearly one-half inch difference in gauge, although no one part was more than one eighth inch out of gauge. With these ties the gauge depends equally upon the two holes punched in the tie-bar, the width of the wrought-iron keys which fit in these holes, and the back of the two cast-iron plates. If the former is one-sixteenth inch wide at each end, the keys each one sixteenth inch too narrow, and each of the plates the same amount scant at the base of the outer jaw, where the key fits through the tie-bar, the error is multiplied six times, and the track will be three-eighths inch wider than the standard, although taken separately the difference would scarcely appear to be worth notice.

It has been found possible to reduce the number of misfits and rejections of small parts from 25 to 5 per cent by carefully supervising the workmen and the tools used for one month. Even the best workmen grow careless when they find that no check is kept upon them, and the low rates at which railway supplies are sometimes contracted for makes it imperative that there should not be any delay in turning out the work, as it is only by hurrying the whole staff that any profit can be made. Firms often send in proposals for the supply of metal ties, although they know nothing about the manufacture of such material, and do not even possess the necessary appliances for insuring good work. The only remedy against this is a complete system of inspection by the railway company's men, who should insist upon the specifications being rigidly adhered to in every particular, as in the case of rails, splice bars, switches, and other track material.

Mr. Bricka, of the State Railways of France, stated in 1892 that it was admitted that metal ties usually failed at the holes for the rail fastenings, and that he had made investigations as to the causes which influence this deterioration.

> The most generally known cause, and one which is often stated as a serious objection to the use of metal ties, is the formation of small cracks, which, under the vibration due to traffic, increase until the tie has to be removed. The repeated shocks and vibrations from trains are not in themselves sufficient explanation; for in bridges, engines, car frames, etc., iron and mild steel resist such constant conditions of wear, and, when of suitably calculated dimensions, no cracks occur. He therefore conducted tests to measure the strength at the holes, using ties from two different steel works, and exerted on one of the sides of the holes, 10 inches wide and 0.4 inch thick, a compressive force analogous to that produced in the track. According to these tests the resistance should average about 30,800 pounds per mm., and should not descend below 22,000 pounds. Then, according to the tests of Wohler and Spangenburg, the repeated effects, even indefinitely, in the same direction, only cause a change in the metal if they exceed the limit of elasticity. The lateral blows which can be exerted on the rail fastenings certainly do not attain the limit of elasticity corresponding to the rupture, for (as proved by the duration of the fastenings on wooden ties) the efforts of this kind are always, in normal conditions, below the figures. Careful examination of holes punched in the ties enable it to be seen that the production of the cracks, if aggravated by transverse blows on the track, is due to a different cause, and one easy to avoid. The punched holes are usually rectangular; and if one considers the sharp angles it is evidently impossible that the punching can be done without tearing the edges of the hole. This, it is thought, can be remedied by rounding the corners to a radius of 0.12 inch. If a number of such ties are examined it will be seen not only that the corners are of much shorter radius, but that sharp angles often exist, in spite of the means taken to prevent them. The explanation is that in successive punchings the punch is worn little by little and forms surfaces more or less irregular, which tear the metal at the bolt holes and produce the beginnings of cracks.
>
> I have had indisputable proof of this existence of cracks in unused ties. A little time after the placing of the first metal ties employed on the State railways some

cracks were noticed by the men in charge of maintenance, and I had all the ties examined with great care. The chief of section, to whom this was intrusted, was not contented with examining the ties in the track, but examined also those in the storehouse, which had never been in service. In these latter the cracks were even more apparent, and since then the men in charge of maintenance have not perceived that the number of cracked ties in the track has increased. In order to remedy this evil it is necessary to give to the holes rounded corners of at least 0.12-inch radius, and especially to require that the punches be renewed frequently, for which purpose special supervision of the punching is necessary. It is sufficient to see that the sides of the holes are clean and smooth, and especially that the circular form of the corners is well maintained. I would add that it is easy to prolong, almost indefinitely, and at least for several years, the life of cracked ties by stopping the cracks before they become extended, by means of a small hole pierced at the end of the crack. Ties placed in the track four years ago on which this precaution was taken remain since that time exactly in the same condition as when the cracks were observed.

The lack of care in punching is responsible not only for causing cracks, but also largely, if not entirely, for the difficulty of keeping the track to gauge, which is so often noticed. In nearly all the works the holes are made successively at each end of the tie, without sufficient care to fix the exact relative position of the holes. There are also variations, often excessive, in the dimensions of the fastenings (clamps, cotters, and keys), and the variations of holes and fastenings form a cumulative error if they are in the same direction. As a result, when the track is laid the gauge of the rails is not uniform, and the track appears badly lined and gauged. The section foremen endeavor vainly to remedy this; they never attain regularity, since in rectifying one line of rail they necessarily displace the other. The best plan in such a case is to be satisfied with the imperfect line, which has no serious practical disadvantage, except that the defects of punching the ties and the gauging of the holes may be increased. It is evidently necessary, however, in contracting for new material to insure that these defects may be avoided.

As the steel cross-tie represents the type most extensively used and the type most likely to be introduced more extensively in this country, I give herewith an extract from the paper by Mr. H. K. Bamber (already noted under the head of "Material") on "The manufacture of transverse steel sleepers." He refers principally to the ties in which lugs are stamped up at the rail seat to engage the base of the rail, which is secured by taper steel keys, such as the Rendel tie (India, *see* Pl. 22) and the Cabry and Kinch tie (England, *see* Pl. 1). The manufacture of the former type is a very large industry in England, one firm alone having manufactured up to 1892 a total of 2,800,000 ties, or 130,000 tons, and being able to turn out complete meter gauge ties of this type at the rate of 10 per minute.

There are two methods of rolling steel sleeper plates: (1) Into the form of flat plates; (2) into the form of trough-shaped plates. In the first case, for sleeper plates 13½ inches wide, the section of ingots at about half their length measures 10 by 17 inches, while in the second case the section at the same point is 15 inches square. In either case the weight of the ingot varies from 2,240 to 3,360 pounds. The important point to be remembered, in the rolling of soft steel into thin and narrow plates of great length is, that the metal, unlike hard steel or iron, on being rolled, does not tend to spread in the direction of the width of the plate; and therefore the ingot should always be wide enough to permit of a sufficient amount of compression on the sides which will ultimately form the edges of the plate.

A plate, such as used in the manufacture of the Rendel sleeper (Pl. 22, E. E. R. T.), will be rolled in the following manner: The ingot measures 10 by 17 inches, and the first operation consists in cogging this ingot down to a section measuring 2½ by 14 inches. Compression to the extent of 7½ inches has thus taken place in the direction of the thickness of the plate, and 3 inches in that of its width; the latter being effected by turning the ingot (which now measures 2½ by 17 inches), and passing it through an "edging groove," whose cross section is 2½ by 14 inches. This passage through the "edging groove" is the great feature in securing sound flat plates, and before ingots were compressed in this manner it was almost impossible to obtain a length of plate which was perfectly sound on its edges.

The sleeper may also be made from plates rolled in trough form, in which case the ingot would measure 15 inches square, and would be cogged down to a section measuring 8 by 6½ inches—a compression respectively of 7 and 8½ inches. The advantage to the sleeper maker of rolling plates in trough form is that the same ingot molds and cogging rolls may be used as for rails, whereas special molds and cogging rolls have to be used for flat plates, unless the rolls have been designed for both rail and sleeper ingots.

In rolling flat plates the slab, raised to the proper temperature, is brought to the roughing rolls, which are "boxed," and is further compressed in the four presses until its section measures 13¾ inches wide and ½-inch thick. It is then immediately passed through the finishing rolls, the last pass through which adjusts the plate to section and weight, at the same time rolling on it the name of railway and manufacturer, and the date. The length of a rolled plate is about 120 feet. The weight of sleeper plates is very important and requires most careful watching. Plates rolled from slabs insufficiently heated are sure to be heavy, while if the slab has been overheated the plates may be too light. An allowance of 3 pounds either way on a 120-pound plate is permitted, and should not be exceeded, but the author has found that, with ordinary care, flat plates will not vary more than 2 pounds either way on a plate of the above weight. The weight of sleepers may often be adjusted to a nicety by the judicious use of cold water on the rolls. The points to be watched are the width of plate, thickness of edges, and weight per plate.

The ingot from which trough-shaped plates are to be rolled measures, after cogging, 8 by 6½ inches at its cross section. This ingot, or rather slab, when reheated is passed through the roughing rolls. [These first break it down into approximately hour-glass section, and then by six more shapes gradually give it the trough section —E. E. R. T.]. The roughing and finishing rolls can not be "boxed" like those for the flat plates, so that one roll may move transversely independent of the other, any slackness in the fit of the brasses in the roll standards at once affecting the relative thickness of the two sides of the plate being rolled. If a slab, through unequal heating in the furnace, is somewhat softer on one side, the colder and harder side offering more transverse resistance to the rolls will cause them to draw hard against the hotter and softer steel, and so result in an inequality in the thickness of the two sides, often amounting to $\frac{3}{32}$-inch in the finished plate. This is very detrimental to the proper shaping of the sleeper under the press, and frequently affects the position of the clips or jaws under the punches, and has, in the author's experience, been the cause of a very large number of rejections. Trough-rolled plates curve considerably in cooling, consequently their adjustment on the press block is very difficult, and in many cases impossible. The weight of trough plates varies considerably, frequently to the extent of 12 pounds on a standard 120-pound plate.

Steel sleeper plates, both of flat and trough section, are shaped while red hot under a hydraulic or steam press, to which are attached suitably shaped cast iron molds. Of these molds, that forming the under or concave part of the sleeper is usually fixed to the bed of the press, while the upper block is bolted to the top table, which in turn is attached to the hydraulic ram and is movable vertically, the ends of the table sliding in grooves cast in the standards of the machine. Formerly the bottom block was cast in two pieces, so that, if one end failed, it might be replaced without removing the whole block. This arrangement, however, gave rise at times to serious defects in the sleepers, for however tightly the blocks might have been bolted to the machine, the repeated shocks sustained when the heavy top block descended invariably caused the two halves to be moved out of line, marking the sleepers very badly, indeed, sometimes nearly shearing them in two where the blocks met. Scale also got under the blocks, entirely altering their proper inclination and spoiling the sleepers. The top block or mold may with advantage be cast in two pieces, and these should not be too rigidly fixed to the machine, as they readily adjust themselves to the plate which is being pressed; and in the case of trough-rolled plates, the thickness of whose sides often varies very considerably, this is a great advantage, as it relieves the ram of much of the side pressure brought on it by such irregularities of thickness. The blocks have chilled surfaces.

The most important of all the operations which take place in the construction of steel sleepers of the "inseparable clip" type is that of the formation by punching of the clips or rail-fastenings. The life, and therefore the value of the sleeper itself, depends upon the strength of these fastenings, while the accuracy of gauge, or distance between the rails, is determined by their proper relative position. It is well known that if steel is punched either cold or at a low heat, the metal surrounding the punched portion is very injuriously affected; but that if annealing is afterward resorted to, the strains set up in punching are to a certain extent removed.

Unfortunately it is not possible to anneal an article of irregular form and section without its becoming distorted in cooling to such an extent that the amount of after adjustment required precludes the possibility of the cheap and rapid manufacture of such an article. For this reason steel sleepers can not advantageously be punched cold and afterwards annealed. The only alternative, then, is to form the rail fastening while the sleeper plate is at a good red heat, and to complete the manufacture of each sleeper before its temperature has fallen to anything like a black heat. In punching sleeper plates at a red heat two difficulties present themselves, (1) that of maintaining a proper relative position between the fastenings, owing to the irregularity in the contraction of plates, either from the quality of the metal or variation of temperature at the time of punching; and (2) that of keeping the punches and dies, which constantly come in contact with the red-hot metal, sufficiently cool to insure keen cutting edges without lowering the temperature of the sleeper itself in the neighborhood of the jaws.

The author carried out experiments on a large number of sleepers, with the view of ascertaining the most suitable temperature for the formation of rail fastenings of the type used on the Indian state railways. The steel used in these experiments was uniform in quality and of equal tensile strength.

(1) Of clips punched in cold plate 100 per cent broke off short on being bent back with the usual testing spanner through an angle of 10°. (2) Of clips punched in cold plates which were afterwards annealed, 50 per cent broke off at an angle of of 20°, while 50 per cent broke off at an angle of 90°. (3) Of clips punched in plates which had been heated to a bright cherry red and allowed to cool down to a black heat before being punched 66 per cent broke off short, while the remainder failed before reaching an angle of 30°. (4) Of clips punched in plates at a black heat and afterwards annealed, 91 per cent bent back double on themselves, while the remainder stood at an angle of 90° before breaking. (5) Of clips punched in plates at a cherry-red heat all clips bent back double, while the result of tests made on plates punched at a red heat and afterwards annealed was equally satisfactory. These experiments show very clearly the danger of forming the rail fastenings on a sleeper plate which has become too cold before reaching the punching machine, and the absolute necessity of punching the metal while at a good red heat.

Given the proper temperature, there are two methods of forming the rail fastening: In the first the clips are punched at once to their proper position, while in the second they are punched deeper and afterwards brought back to proper position by being hammered on suitably-shaped pieces of metal called drifts. The former is the cheaper, but in view of variations in punches, dies, temperature, etc., the latter is the better. On leaving the press the sleeper is immediately taken to the punching machine, turned on its back, adjusted to position, and the clips punched down and either drifted or not. The punches may be cooled by water.

Some manufacturers secure accuracy of gauge in the sleeper by making distance marks on the sleeper plate and blowing steam onto it until these marks trammel correctly, when the clips are at once formed; or, if the distance marks are found to be near each other, the temperature of the plate is raised and the gauging again tested. Others, again, judge by practice the proper heat, and although from time to time, through carelessness, variations of gauge may occur, with proper care and attention on the part of the workmen the gauge is sufficiently accurate for all practical purposes. About three-sixteenths inch total variation is allowed by the terms of the specifications, but the author has notified that plate layers (track men) make short work of adjusting a sleeper which is either three-sixteenths inch too wide or too narrow to gauge.

The following suggestions are made in regard to the manufacture: (1) The steel should not be of higher tensile strength than 30 tons per square inch; (2) tensile tests of the steel should be made as often as possible, this test being the best guarantee of the after behavior of the plate in punching; (3) the plates should be rolled in the flat form in preference to the trough; (4) when possible, the sleepers should be pressed and punched immediately on leaving the rolls, care being taken that only such a number of plates are pressed as will insure the last being at good heat after leaving the punching machine; (5) the sleepers should in no case be dipped in tar at such a temperature as to give rise to thick, yellow fumes (6) at least 2 per cent of the rejected sleepers should be tested, and 3 per cent weighed separately daily.

In this country the manufacture has not yet attained much importance as a commercial industry. The Schoen Manufacturing Company has made 18,000 of the New York Central Railway ties. The Carnegie Steel Works have made the Standard ties, and the Lackawanna Iron and Steel Company has made the Morrell ties, while the C. W. Hunt Company has a large business in track for industrial railways, and the Daniels Steel Railway Tie Company is rolling and introducing street railway ties. Mr. Charles S. Schoen, in August, 1894, wrote me as follows:

> The published price of $2.50 was the price at the time of manufucture. We could, however, furnish these ties in quantities at the present price of steel for less than $2. We have not made any excepting the 18,000 for the New York Central, the difference in price between a metal tie and one of wood being so great that we did not think it a good enterprise from a commercial standpoint. The price of metal, however, is getting so low that there may be a future for metal-tie business.

CORROSION AND PRESERVATIVE TREATMENT.

Rusting and corrosion usually occur only in very damp places (especially in wet tunnels) and in soils impregnated with salts or alkaline matter, especially if the soil is moist. In long wet tunnels the corrosion is probably hastened by the effects of the acids and gases from the smoke and the engine cinders. On the Gotthard Railway (Switzerland) the wear and rusting at the rail seats of ties in long tunnels necessitated many renewals of the earlier ties, but no renewals of those laid since 1887. On the Elberfeld division of the Prussian state railways wooden ties are used in such tunnels. The alleged corrosion of steel ties in the track on the East Coast Railway (India) is said to have probably occurred while the ties were stacked on the seabeach where landed, but corrosion in salty soil has been reported from the Northwestern Railway and other Indian railways, as well as from Egypt. The light steel ties on the Barquisemeto Railway (Venezuelà) are said to be corroding rapidly, while those of the Bolivar Railway are satisfactory. The Baden state railways (Germany) have been making experiments with tar and paints to check rusting in the tunnels, while the Charleroi local railways (Belgium) report renewals necessitated by rust after seven years' service. A good deal of the trouble in this direction is probably due to poor material or poor work in the preservative process.

Steel ties made in England are usually coated with a mixture consisting of 3 parts coal tar and 1 part tar oil, which is kept in a boiling condition by the passage of the hot plates through it, the plates having a temperature of about 300° F. Mr. Bamber states that it is very essential that the ties should not be so hot at the time of dipping as to cause the solution to give off thick, suffocating fumes, as the coating formed in this manner flies off almost like coal dust, and is of no use in preserving the tie from rust. The plate should be thoroughly cleaned from scale before being dipped, and the work should be carefully and thoroughly done.

FORM AND DIMENSIONS.

In designing or selecting a type of tie for metal track particular attention should be given to securing a form which can be easily tamped and will retain the ballast. With the inverted trough section the difficulty of tamping increases with the depth of the trough, but if the trough is too shallow it will not give sufficient stability to the track. For such ties the depth should be at least 3½ inches, for main-track service, with closed and depressed ends, while the width at rail seat should be at least 4 inches. If the tie is depressed in the middle, to allow for a thick covering of ballast, it must be sufficiently stiff in itself and sufficiently well tamped to prevent it from bending in a tendency to become straight, thus widening the gauge. This has been proved on the Eastern Railway of France and other roads. Bolt holes are less likely to start cracks if they are drilled than if punched, and M. Bricka, of the French State railways, finds that cracks can be stopped by drilling a small hole at the end of the crack, no further development of the crack being shown after four years' service. Each tie should be complete in itself and independent of the others, so as to facilitate renewals. In some patterns the tie can only be slipped on at the end of the rail, and in others the rail must be tilted up before its base can be freed from the fixed clips, but both of these plans are decidedly objectionable for ordinary main track. The greatest practicable simplicity is desirable, as shopwork is expensive, and if there are many riveted or bolted connections they are liable to become loose, making a noisy track. In designing a steel tie, two questions to be considered as of equal importance with the perfection of the design, are: (1) What processes of manufacture will the carrying out of the design involve; and, (2) will such processes be more costly than the value of any peculiar features of the design will warrant.

WEIGHT.

This is a very important consideration, and many of the ties mentioned in Part 1 have been shown to be unsatisfactory on account of their lightness, although the design was otherwise satisfactory. It is most unwise to cut down metal merely in order to reduce the first cost of the tie to about the same as that of a wooden tie, as in this way the former may easily be far more expensive in maintenance and renewals than the wooden tie. It is a matter of proper design. The tie must have a certain thickness and weight to stand wear and shocks and to afford sufficient stability, but beyond a certain point any addition of metal is an unnecessary expense, and represents money lying useless in the track. The following remarks as to weight were made by Mr. Fernow in Bulletin No. 1 of the Forestry Division, 1887, and the accompanying table of weights was also given by him:

> As stated before, the first iron sleepers were not successful, on account of their light weight and consequently reduced section. Those introduced in France and Germany in 1864 were only 66 pounds. The fastenings had not hold enough and breaking was frequent where the rails rested on the ties; there was also danger connected with them on account of unsteadiness and increased lateral movement. The results were due to the following causes: (1) the holes of the fastenings reduced the cross section; (2) the punching of the holes made the metal around them more or less brittle; (3) in time the foot of the rail and fastening would eat into the top of the tie; (4) with a rational tamping of the ballast the momentum of reaction of a ballast is a maximum at the cross section, where the wheel load is applied; (5) the impulse of the moving load is transferred directly to the tie at these places.
>
> Increase of weight gives more stability to superstructure. Metal cross-ties weighing 100 pounds have proved quite satisfactory. Those of less weight, 77 to 88 pounds, proved too light. The State Railway of Wurtemberg uses ties of 128 pounds, but the majority of German and Dutch engineers consider 112 pounds fully sufficient to maintain a perfectly steady and permanent road. The following table, giving the weights and prices used by the different German roads, may be of interest:

Name of railway.	Weight of tie.	Average price per ton of metal.	Average price per tie.
	Pounds.		
Imperial Railway in Alsace-Lorraine	126.5	$31.68	$1.79
Bergisch-Markisch, old Vautherin pattern	126.5	30.96	1.75
Same, new Hilf pattern for main lines	98	30.96	1.35
Same, for branch lines	88	30.96	1.22
Links-Rheinisch Railway, old pattern	77	34.48	1.19
Same, new pattern	110	34.48	1.70
Rechts-Rheinisch Railway	106.5	30.70	1.46
Prussian State lines, various	114.5	34.48	1.77
Magdeburg section	120	36.77	1.97
Rechte Oder Ufer	101	42.08	1.90
Hessisch-Ludwigs	98	31.68	1.38
Altona-Kill	101	....	1.60
Wurtemberg State lines	130	37.00	2.14

FASTENINGS.

Bolted clamps of some form or another are by far the most generally used styles of fastenings, and the bolts are usually vertical, passing through the tie. The ties of the New York Central Railway, however, have bent bolts, with the shanks inclined away from the rail, and the Standard and Price ties have clamps held together by horizontal bolts under the rail. The Haarmann combination of hooked tie plate and bolted clamp proves very effective (Pl. 2) and reduces the usual number of bolts by half. This fastening is in use on about 365 miles of track. The plate has an inclined rail seat to give the inward inclination or cant of the rail, which is usual in European practice, to fit the conical tread of the wheels. The outer end of the plate has a lug on top to hold the outer side of the rail flange, and also a lug on the lower side, which takes hold of the tie. On the inner side is a slotted hole, into which the rail clamp fits, the clamp being secured by a T-headed bolt. As there is no bolt on the outside of the rail, the ballast may be filled in to the rail head if desired, thus getting additional resistance to lateral motion. On the German railways it is the practice to widen the gauge on curves of over 6°, and with this construction of track the widening is effected by the use of four sizes of plates and clamps, giving eight different gauges, from 4 feet 8½ inches to 4 feet 9¼ inches. An objection to this, of course, is the complication of parts, but this objection is not so great as it might seem at first (especially under European conditions of track, work and labor), owing to the very much greater permanence of the parts and the great reduction in maintenance with the metal track. The Heindl system also employs a combination of tie-plate and bolted clamp, more complicated than that of the Haarmann system, but Mr. Ast, of the Emperor Ferdinand's Northern Railway (Austria), attributes the perfect security of the fastenings to the use of a tie-plate prevented from motion on the tie, thus avoiding the direct thrust of the rail flange upon the outer fastenings or upon the tie-itself, while the plate also serves to distribute the effects of shocks upon the rail head. In some patented forms of ties the rails rest upon hinged or wedge clamps, so arranged that the weight of trains will cause the clamps to press down upon and grip the top of the rail flange. Such fastenings, however, have little promise of practical result, owing to the wear upon the rail and the fastenings and to the fact that the rail must be depressed before it is tightly held and will rise when the weight is removed, thus making a clattering track. The parts also are liable to rust together and become inoperative. Various suggested forms of fastenings are referred to in the notes on American ties and in the list of patents forming Appendix No. 2.

The style of fastening should be as simple as possible, allowing for adjustment on each tie. The taper keys used for the Rendel ties have the ends sometimes split, so that after being driven the end can be opened out with a chisel to prevent the key from working loose; but as a rule this is not found to be necessary, and in fact the splitting of the ends is now very largely omitted, thus reducing the cost of manufacture. The keys have a taper of about 1 in 64. On the Indian ties the space between the edges of the jaws is less than the width of the rail flange, and it is therefore necessary to tilt the rail to put it into place. This has the disadvantage of preventing the removal of one tie independently of the rest in a length of rail, as, in order to remove one, the two rails must be uncoupled and taken off. On the other hand, the rail can not get off the tie should the keys become displaced. On the Cabry tie, of the same type, used by the Northeastern Railway, England, the ties can only be keyed on the inside, and therefore the gauge can not be widened except by the use of special ties. The rail is placed in position by tilting it and passing one side of the flange under the inner or longer clip, sufficient space being left for the outside of the flange to clear the shorter clip. It is then dropped onto the rail seat and slid back under the shorter clip, and the steel taper key is inserted between the rail flange and the longer clip. The flange is overlapped by both clips, and the rail can not be forced out of position, even should the keys be displaced.

Trials are to be made in India with steel ties whose lugs are farther apart than the width of rail base, a distance piece being inserted between the rail and inner lug before the key is driven on the outside, and this arrangement will admit of much closer adjustment of gauge on curves, etc.

The points for consideration in fastenings are:

(1) By the insertion of a plate between the hard rail foot and the softer tie, the latter would be saved and its natural straightness preserved, avoiding injuries in the shaping by rolls, in bending, or otherwise.

(2) A rational and direct transmission of the attacking forces from the rail to the tie should be effected.

(3) The fastenings must be such as to keep the gage constant on the curves as well as on the straight road, and to permit the elimination of unavoidable faults occurring in fabrication.

(4) To allow shimming up, where the action of frost makes it necessary.

The forces which work upon the fastenings are:

(1) The horizontal forces tending to press the rail foot outward.

(2) The vertical forces tending to raise the inner edge of the rail foot.

To counteract these forces, it is necessary, with bolt fastenings, to protect the bolt in its entire length against side forces tending to bend it or wear it away. To effect this the bolt must be placed as near the rail foot as possible, so as to reduce the leverage of the vertical force as much as possible. Small number of parts and a simple form are most desirable. The nature and good service of the fastenings has also great bearing upon the cost of keeping the road in order.—(*B. E. Fernow. Forestry Division, Bulletin No. 1, 1887.*)

CHAIRS AND TIE-PLATES ON METAL TIES.

Experience has shown that metal ties give better results when used with T rails resting directly upon the tie (or upon a thin tie plate or base plate) than when used with double-headed rails resting in chairs attached to the tie. This latter is especially the case when the ordinary European style of cast-iron chair is used and bolted to the tie, as the height of the rail above the tie causes a leverage on the chair bolts which leads to loosening of the bolts and wearing of the bolt holes. The Western Railway of France, however, reports satisfactory results with chairs cast upon the tie, and Mr. Bricka, chief engineer of the French State Railways, considers that ties carrying the rails in cast-iron chairs will have a greater length of life. Where T rails are used they are most generally laid directly upon the tie, and with success, but in some systems of track a metal plate is placed between the rail and tie so as to prevent wear and to distribute the load. Among such systems may be mentioned the Haarmann (Germany) and the Heindl (Austria), the former of which gives a very simple and effective fastening. The Netherlands state railways (Holland) and Normanton and Croydon Railway (Queensland) have also tried the use of plates. Open-top trough ties, with a block of wood or other nonmetallic material under each rail, have been tried, but are in a very decided minority. (*See also* the paragraph on metal contact.)

ADJUSTMENT OF GAUGE.

In view of the use of metal ties on curves, it is desirable to have some means of widening the gauge of track, and this is best effected by the rail fastenings. In German practice this seems to be carried to an unnecessary refinement, as in the Haarmann system, which employs four sizes of tie plates and clamps, giving eight different gauges, from 4 feet 8½ inches to 4 feet 9¼ inches. The Baden state railways, however, have an even greater number of variations, effected by square washers on the bolts (which washers bear against the rail flanges); these washers have the bolt hole eccentrically placed, with a different width in each side, and varying the positions of the four washers of each tie gives no less than twenty different gauges, varying by 1 millimeter (0.04 inch) each. It would seem to be almost impossible to carry this out in full, and the arrangement necessitates a careful planning of the positions of the washers and still more careful work in track laying. The latter can only be carried out by skilled men, but such extreme fineness of detail (going beyond practical requirements) is characteristic of German practice. Even if desirable in itself, such a system could not be carried out in this country, but as a matter of fact it is too complicated to be desirable and serves no useful purpose. As the gauge is fixed by the washers, any wear or unevenness of the washers or any slight wear or irregularity of the rail flange, will at once destroy the theoretically nice adjustment of gauge. With the Rendel steel ties, as used in India, the adjustment may be effected by placing one or both keys on the inside of the rail, or by placing a distance piece between the inner lug and the edge of the rail. The actual width of gauge should be determined always and only by measurement between the rail heads, and a very simple and effective means of adjustment is afforded by the bolted clamp fastening of the New York Central Railway steel ties (Pl. 1). On slackening the nuts the rail can be shifted to the proper position shown by the track gauge; the clamp is then shifted (having a slotted hole) to bear upon and against the rail flange, and the nut screwed home again. Owing to the wedge shape of the clamp it can not be forced outward by the thrust of the rail, as might be the case with a vertical bolt and a slotted clamp with flat top. This arrangement has also been applied by Mr. Katté, the chief engineer, to wooden ties, using screw spikes driven at an angle. The gauge can thus be adjusted by merely slackening the spike sufficiently to allow of moving the rail and clamp, and then screwing it tight again.

METAL CONTACT.

A common objection urged against the simplest form of metal track with T rails resting directly upon cross-ties, is that the rail base will wear into the tie, but as a matter of fact this is not often found to be the case, especially where strong and efficient attachments are used to fasten the rail to the tie. This, however, may be avoided by the use of metal tie plates, as noticed under the heading of "Fastenings." Another objection urged is that metal contact will cause considerable noise and rattling, which will be unpleasant to passengers. Rattling can not occur if the fastenings are tight, and there is little to fear from any other noise, since the ballast will usually absorb the vibrations. Several reports in Part I state that there is no difference between the noise of trains riding over metal ties and those over wooden ties; or that the difference is so slight as to be inappreciable, or at any rate not to outweigh the advantages of these ties. On the Baden state railways (Germany) the rattling noise ceases as soon as the ties have become firmly bedded in the ballast. In India several arrangements of cushions or bearing blocks have been used, but generally abandoned, and the Great Indian Peninsular Railway reports that such blocks caused corrosion and pitting of the rail (double-headed section) to such an extent that the lower head could not be used for running, and the ties now made have a direct bearing of the rail upon the cast-iron bowl. The Indian Midland Railway, however, uses felt cushions under the rails. Bearing blocks of wood and vulcanite are used in this country with the Standard, Morrell, and Price ties.

In this connection it may be noted that on the Eastern Railway of France sheets of tarred felt are laid between the rails and creosoted pine ties, while many European railways use felt sheets under the cast-iron chairs for double-head rails.

CLOSED AND OPEN ENDS.

It is hardly necessary to again point out that steel trough ties must have closed ends or other means for affording resistance to lateral motion in the ballast. The Webb (English) ties on the Pennsylvania Railway have had to be held in line by timbers placed between the ends of the steel ties and the ends of the wooden ties of the parallel track, and on the Western Railway of France it was found necessary to close the ends of the channel iron ties by riveted crosspieces. Diaphragms riveted inside the trough at some distance from the ends have also been tried, while in two open-top trough ties in use in this country a portion of the bottom is cut away and bent down (Morrell tie), or up into the trough (Standard tie). With the Daniels corrugated plate tie there is a patent "anchor" for use on curves, consisting of a curved piece of corrugated metal attached to the tie at the rail seat and projecting down into the ballast. Such special appliances, however, are not desirable, as already pointed out. In Europe the end of the tie is usually bent down below the bottom and flared out to extra width, while the whole end portions of the tie, outside the rail seats, are frequently bent downward below the body of the tie.

SPACING OF TIES.

In this country the proper spacing of ties, viz, closer at the joints than at the middle of the rail, is not so generally observed as in Europe, and wooden ties are much more closely spaced here than in Europe. On the New York Central Railway different arrangements have been tried with the steel ties, and the best results are said to be obtained with a uniform spacing of $25\frac{1}{16}$ inches, which seems, however, to be unnecessarily close for intermediate ties under heavy rails. In Europe a common practice is to space the joint ties 21 to 24 inches, center to center, the next two or three ties 24 to 30 inches, and the others 33 to 39 inches, center to center.

EFFICIENCY AND DURABILITY.

Careful consideration of the statements and records in Part I leaves no room for doubt as to the efficiency of metal ties in making a good, smooth, safe, permanent, and economical track, provided, of course, that a suitable system of tie and fastening is used. Mr. Bricka, engineer in chief of the state railways of France, in an address at the International Railway Congress, 1892, pointed out that the differences of opinion between engineers as to the question of metal ties must not be ignored.

There are strong partisans and determined opponents, not including those who are influenced by prejudice without having made a careful study of the matter, and between the statements of one and the other it is difficult at first to see the truth. Mere affirmative or negative statements are not enough, and between the varying results presented by both sides the only way of arriving at the truth is to seek thoroughly for the causes which have led to success in one case and to failure in the other. Taking the question of durability, it seems to be established, even by very unfavorable experience, that the metal ties should carry a traffic of at least 150,000 to 200,000 trains; a minimum number which Mr. Bricka thought could be far exceeded, especially for ties having the rails carried in cast-iron chairs. That number represents, for lines having not more than 5,000 trains per year, a life of thirty to forty years; while for lines on which the number of trains reaches 30,000 per year, the life will be only from five to seven years. Railways with such a number of trains, however, are very exceptional, the majority (especially in France) carrying a traffic of not more than 5,000 trains on single track, or 10,000 on double track. The estimate, therefore, is very reassuring for lines of the latter class. The consideration of the traffic and of the details of manufacture, already noted, are sufficient to explain the widely different opinions held by engineers respecting the use of metal ties. Such ties, of the most suitable material and best quality, properly manufactured, punched with care and of suitable dimensions, are easy and economical in maintenance, and should have a very long life in tracks with light or moderate traffic. On lines with heavy traffic it is probable that with a good type of tie, well manufactured and carefully punched, the life of the ties may be prolonged beyond the figure of 200,000 trains, though in exceptional cases this life may correspond to a less number of years than that estimated for wooden ties. As already noted, however, lines with such exceptionally heavy traffic represent but a small fraction of the total railway mileage. It may be said, therefore, that neither special merits nor demerits can be sweepingly attributed to metal ties. In each case where the application of metal track is considered to be justifiable, it is necessary to consider the advantages which the ties present, estimating their life by the number of trains and average tonnage, and not by the number of years. It is necessary also to have careful inspection of the manufacture, and, in case of failures, to seek the causes in the facts that can be observed, and not to deduce them from preconceived ideas, and to attribute to the system itself the consequences of faults committed by those who use it. To enable any practical deductions to be drawn as to the life of ties, it is absolutely necessary to have details of the soil, climate, and atmospheric conditions, curves, grades, and the number, weight, and speed of trains.

The life of iron ties has been variously estimated by those in favor of the system at from thirty to fifty years; opponents place it at not more than twenty years, or the same as that of the best wood ties. This last estimate is, however, disproved by the more than twenty years' experience with longitudinal ties on the Brunswick railways. These were laid in 1864, and in 1882, on thorough inspection, were found but slightly affected by rust. In fact, iron ties suffer less from atmospheric influences than wooden ones.

Ties on the Bergisch-Märkisch lines, after being laid for eight years in a badly drained ballast, were found to be not more affected by rust than the rails. Mr. Kalff, at the convention in Brussels, stated that metal sleepers laid down twenty years ago were found in perfect condition. Only, for ties kept in reserve by the side of the line or in damp tunnels and similar localities, or if transported over the sea, a coat of tar or paint might be found advisable.

With the better form and heavier sections now used, the breaking of a tie is so unusual as not sensibly to affect the annual charge. Whatever the cause, steel rails and ties undoubtedly rust much faster than those made of iron.

Mr. P. H. Dudley, C. E., an expert on railway matters, says: "So far as atmospheric agencies are concerned, the German experience would be a good guide here. The oxidation of rails at least shows in most localities no greater rapidity than in Germany. Failure in this country of metal ties, as far as I have seen them used, was due to their form not meeting the conditions required of a metal tie."—(*B. E. Fernow, 1887.*)

INFLUENCE ON ROLLING STOCK AND RAILS.

The reports made to the International Railway Congress show the effect on wear of rolling stock is inappreciable, but sometimes is favorable, in that it slightly reduces the wear, owing to the smoother riding of the trains. In the quotation given below it is stated that metal ties do not bend, but, as a matter of fact, if the ties are not stiff enough the ends, beyond the rail seats, will bend up, as in the South Australia trials. It is most probable that the wear of rolling stock and rails is practically unaffected by the introduction of steel ties. The following is an extract from a statement by Mr. B. E. Fernow, published in Bulletin No. 1 of the Forestry Division of the U. S. Department of Agriculture, 1887:

The effect of the material of the tie on the rolling stock is difficult to ascertain, and not much is known about the influence of metal ties. But it may be noted that on the German railways in 1883 the number of tire breakages per 100 miles of line with wooden ties, metal cross-ties, and metal longitudinal ties, were respectively as 7.25 to 5.96 to 2.74; showing the advantage of the long-tie system, by which the shock at rail joints especially is diminished. The weight of the entire superstructure in itself and the good tamping of the ballast conduce to its quiet position, and serve to lessen the loss in rolling stock and the cost of maintenance.

Mr. C. P. Sandberg, the well-known expert on rails, says:

"It is a great mistake to diminish the rail section in consequence of the adoption of metal ties, as has been done on some railways, for the metal in the tie can in no sense make up for the metal in the rail. The strong rail has the power of spreading the effect of the concussions from the rolling stock over several neighboring sleepers, thus dividing the effect, while the light, weak rail will concentrate the blows on one or two ties. The heavy flange rail also is a *sine qua non* for the success of a metallic permanent way, if by 'permanency' be meant anything approaching thirty years or more."

In the Revue Générale des Chemins de Fer, April, 1886, p. 260, a comparative table is given, showing the respective durability of rails on ordinary roads with wooden cross-ties, and roads on metal ties with the Vantherin and the Hohenegger system (longitudinals 32 feet long with one cross-tie to each length), and the Hilf system (longitudinals of 24¼ and 29¼ feet length with one cross-tie to each length).

The comparative results show: (1) That with the Vantherin system the wear is three times as much as with good wooden ties; (2) with the Hohenegger system the wear is four times as rapid; and (3) with the Hilf system it is four to five times as rapid as with wooden ties.

Metal ties do not bend visibly like those of wood, but descend evenly, and the leverage of the momentum of deflection at the intersection of the rails and ties is greater than in the case of wooden ties; but if the strain be limited to, say, 4 tons per square inch for iron, and about half as much again for steel, there is no fear for the resistance of metal sleepers.

TRACK LAYING.

The laying of track with metal ties presents but little more difficulty than similar work with wooden ties, except where complicated systems of fastenings are used. Particulars of the operations will be found in the statements respecting the Bengal and Nagpur Railway (India) and the Puerto Rico Railway (West Indies). In regard to bolting up the rail fastenings, it is well to note that at first the bolts may need occasional tightening until all the parts are well settled together. The nuts should be screwed up tight, but special instruction should be given that the wrenches must not be twisted violently or with all a man's force. Such action will tend to damage the track by straining the parts or even stripping the threads of the bolt or nut. (*See* New York Central Railway.)

In laying the Rendel steel ties used in India, the ties are first placed and the right-hand rails are then strung in position resting upon wooden blocks about 10 inches high, a pinch bar being held between the ends to keep the expansion spacing open while the rails are lined in, and one end of each tie lifted until its lugs engage the rail flanges (the width between the lugs being less than that of the base of the rail). After the wooden blocks have been removed and the rails have been dropped into place, an expansion shim is inserted between the rail ends and the rails driven close up. One of the keys at each joint tie must be driven before the splice bars are fitted in, as it can not afterwards be driven from the splice bar side. The left-hand rails are then thrown onto the ties by levers, slipped between the lugs into the rail seat by pinch bars, and then forced home against the inner lugs while at the end of each tie raises it up to the rail. Mr. W. H. Cole, in a paper presented to the Institution of Civil Engineers in 1894, stated that in 1889 on the Mooltan division of the Northwestern Railway, India, about 55 miles of 60-pound T rails on wooden ties were replaced by 75-pound T rails on steel ties, with the trains running, in about three months. The men were well drilled in a very short time, and everything went like clockwork. As soon as the rails were placed on the blocks, 10 men stepped forward, raised one end of the ties, and simultaneously hitched them onto the rails. The width between the lugs being less than that of the rail base, the outer lug was pulled well over the flange of the rail and the inner lug was then easily forced over the inner side of the flange. The blocks on which the rails rested had sloping tops, so that the ties hung from the rail at one end and had the other end resting on the ground. Ties are to be tried, however, having the width between lugs sufficient to admit the rail base, a distance piece being then placed between the rail base and the inner lug.

In regard to the slow introduction of metal ties on English railways, it may be noted that the trackmen there (as in some other countries) are strongly prejudiced against such ties, of which they have had no experience; and these men, even including inspectors and foremen, sometimes assert that should steel ties come into general use a higher class of labor would be necessary to lay and maintain the track, as the men must have some amount of mechanical knowledge. The "Indian Engineer," in commenting upon this state of things, says that while the wages paid to track laborers in Europe and some parts of America are not sufficient to induce intelligent men to remain in the service, it is not to be believed that English laborers will prove less apt than Indian coolies or African negroes in learning how to handle metal ties when once the prejudice is overcome. The same is true of this country, for the average section gang on a well-managed road should be able to attend to the laying and maintenance of metal ties equally as well as the laying and maintenance of wooden ties. It may not be amiss to point out here, however, that on too many American roads the importance of the track work and the advantages of having it properly done are not sufficiently recognized. As a result, very poor wages are paid by such roads, and inefficient men working for poor pay can not be expected to do first-class work. In many cases a little extra expense for a better class of labor would effect economy in track work and operation. If a road should go to the expense of putting in good steel ties it would be the height of folly to leave them to the tender mercies of unskilled trackmen.

BALLASTING.

The statements in Part I show the use of various materials for ballasting metal ties, but for steel cross-ties the best material is found to be one-half inch to 2-inch broken stone or clear gravel, as noted particularly on the Jura-Simplon Railway (Switzerland). Burnt clay or slag would probably be almost equally good, though in regard to the latter it is possible that certain grades of slag may exercise a corrosive effect upon the metal. On the Netherlands state railways it is considered that a greater depth of ballast is required with metal ties than with wooden ties, but this does not appear to be the experience elsewhere. In regard to the shaping of the ballast it is a very general practice to cover metal ties with the ballast (which would be detrimental to wooden ties on account of holding the wet and causing rot, except in very dry and hot districts), thus insuring extra weight and stability, as in the New York Central Railway steel track (Pl. 1). As noted in the statement from the Delaware and Hudson Railway, difficulty was experienced from shifting of the track and blowing out of the ballast, evidently due, in part at least, to the sloping down of the ballast at the ends of the ties, as the common form of road bed where wooden ties are used, a form which need not be blindly followed when other kinds of tie are used. It is well to fill in the ballast over the ties, leaving only the fastenings exposed for inspection, and to shoulder it out for some distance beyond the ends of the ties. Care must be taken in tamping to have all the ties equally well tamped, as, if one tie is well tamped and adjacent ties more loosely tamped, the extra load upon the former may bend it (if of steel) or break it (if of cast iron). With wooden ties the only effect would be to make a rough-riding track. Section foremen putting in metal ties for the first time are found to be apt to spend more time than is actually necessary in tamping the ties solid, and find after all that the track has to be gone over again before it is fit to be finally dressed off. The best plan is to tamp each tie fairly solid when it is put in, and after two or three trains have passed over the road surface up two or three rail lengths, at the same time taking care to tamp hardest under the rail for about 10 or 12 inches, and somewhat lighter at the ends and towards the center. With the Indian standard gauge of 5 feet 6 inches, tamping for a width of 21 inches under each rail is found to be quite sufficient, and this leaves a space of 2 feet 2 inches in the center of the tie which is left quite free, the ballast being filled in loosely with rakes. Metal ties generally require a third tamping before they can be said to be thoroughly bedded, but after this they should require less attention than wooden ties.

It would seem as though a soft material, such as sand, would be best fitted for ballasting cast-iron bowls and plates, but this is not found to be the case, and the Great Indian Peninsular Railway is replacing all sandy and earthy ballast with 1-inch broken stone. In Australia and on some of the new pioneer railways in Africa the ties are packed with soil. In this country we know a great deal about earth or "mud" ballast, but it is not likely that any road using such material will put metal ties in its track. In good clean gravel the work of tamping should require fewer men per mile after a year or two, but in the soft black cotton soil of India, which practically never becomes really consolidated, it is more difficult to tamp and maintain steel ties than wooden ties.

If the ballast inside the rails has not been properly packed, so that only the portions outside the rails sustain the whole load, the momentum of deflection will double, but even then there will be nothing to fear. If, on the contrary, only the central portion of the tie between the rails bears upon the ballast the maximum momentum of deflection, which may thus be increased to five times its ordinary amount, will be transferred to the center of the tie. Experience has shown, however, that this will not occur if care be taken not to pack the central portion of the tie.

Filling hollow sleepers with ballast having a certain amount of cohesion is not recommended, as no degree of elasticity in the filling substance can increase the resistance to deflection. The tamping of the ballast under steel ties must be so done that the middle of the tie is either empty or at least not compactly filled with ballast, while for a distance of 12 to 15 inches on each side of the rail the ballast must be well tamped. It is also important that during the first few months after the ties are laid the road should have great and constant attention until the bed becomes consolidated. The cost of this ought to be considered as part of the cost of laying the road.

The metal tie acts best on firm ground. Thus, on the Liége-Limbourg line there were 20,000 metal ties which had not been touched for twenty-two months and the road continued in a most satisfactory condition, working trains running at a maximum speed of 38 miles per hour. Lengths of ballast of medium quality in which wooden ties appeared to be dry have proved unsatisfactory with iron ties. By means of their pumping action the latter draw the wet up from below and work the ballast into mud, making a solid bed impossible. This working up into mud occurs also with wooden ties, but only after the ballast has become completely impermeable for water, and requires renewing anyhow. The reasons for this difference may be stated as follows:

(1) The iron ties have twice the deflection of the wooden ones.

(2) On account of the accurate fastening of the rail to the iron tie, it shares the whole vertical motion of the rail, whereas with wooden ties the play of the foot of the rail in the spikes and the compressibility of the timber both tend to lessen the deflection of the tie.

(3) The hollow body of the iron tie is very favorable to the formation of an air-tight cavity, inducing the pumping action above referred to.

(4) The under surface of the wooden tie lies twice as deep as that of the iron one.

The working up of the ballast into mud by iron ties on certain trial lengths has interfered with their more general introduction, whereas the failure should have been put down to the inferiority of the ballast and its impermeability to water. It would be found that in similar ballast an accumulation of moisture at the bottom of wooden ties takes place. Good ballast must fulfill the following two conditions:

(1) It must be capable of being beaten up under the tie into a firm mass, so as to afford the greatest possible resistance to the deflection when the load comes upon the tie and the greatest possible resistance to being shaken loose.

(2) At the same time the material must be such that between the ties there may be in it interstices for the passage of water, but also the greatest possible cohesion and friction, to prevent slipping and to distribute equally the pressure of the load.

Broken stone fulfills these conditions best, especially as to drainage.

Water remains longer between the rails with the longitudinal systems than with cross-ties, as, on account of the solid body below, it is drained off more slowly; therefore in winter the gravel bed forms a frozen body. If this thaws from above the longitudinals may lie entirely in a thawed bed and the cross connections in a frozen bed. Then the cross connections are points between which the long ties with the rails must lie free or imperfectly supported. From this occurrence danger must be apprehended, especially in changing weather.

Another objection is made on account of frost heaving. If in a wooden structure one rail is thus lifted the other can be accommodated; but in iron structures a greater diversity of heavings must occur, which are not so easily remedied. The Royal Prussian Railway management, however, using Haarmann's longitudinal system, finds this objection not sustained even in protracted frosty weather, and considers this system efficient as well as easily and cheaply maintained. On the Brunswick railways the iron superstructure (longitudinals) upon hard subsoil is not easily maintained in wet weather. The same experience has been made in Lorraine; but on the Rhenish system, on well-drained ground, no difficulty is experienced.

On the road from Calbe to Blankenheim (mountainous), where more than 60 miles of Hilf longitudinal, are laid, the cost of maintenance is double that of wooden ties, the reason, among other causes, being the bad condition of the bed material, a loamy and clayey sand, which becomes slippery after every rain. A simple cross-tie system and broken-stone ballast is recommended on badly drained soils.—(*B. E. Fernow, 1887.*)

The following remarks are from a paper published in 1887 by Mr. Cantagrel, a French engineer:

The quality of the ballast is a matter of some importance. In England trials were made with the Macdonnel track to compare the merits of broken-stone and gravel ballast, with results in favor of the former. With the Webb tie a ballast has been used composed of slag and furnace cinder; it keeps together well, but ought to be given up, since in three years ties weighing 180 pounds lost 40 pounds by oxidization, caused by the action of damp on the ballast, which contained considerable sulphur. In Belgium broken stone is used with slag from the blast furnaces, broken to pass through a 2-inch ring. Formerly the finer part was spread over the surface, but as it caused dust to be raised by passing trains its use was abandoned. Mr. Jungbecker states that the best ballast is stone broken to pass through a 1¼-inch or 1⅝-inch ring. Coarse gravel and rounded pebbles of sandstone or quartz are also good, but shaley or clayey material should never be used. The primary condition for all metallic substructure is a well-drained and dry ballast. On the German railways it is prescribed that the frost should not reach the water level, and it is therefore necessary to have a perfectly permeable ballast and to place the level of the flow of water as low as possible. In Holland quarry sand is much used, river sand being too fine, but preference is everywhere given to broken stone and blast-furnace slag.

RENEWALS.

One of the great advantages of a good metal track is the great reduction in tie renewals and consequent disturbance of the track. As, however, renewals must occasionally be made, the ties should be of such pattern that any one tie can be removed and a new one put in without disturbing any other ties. It is sometimes claimed that metal ties may be introduced gradually by using them in renewals of worn-out wooden ties, but such a practice is not to be recommended, as it would result in a hard-riding track, and when a road does adopt metal ties it ought to be able to lay them on reasonable lengths of track. An Indian engineer states that a metal tie which can be used indiscriminately with wooden ties possesses a distinct advantage over types which can only be laid continuously, as it admits of the change from wood to metal being made gradually; and the expense of renewals being thus spread over a number of years does not affect the yearly balance sheet to such an extent as would be the case were the whole of the wooden ties removed at once. He says that Indian experience has proved that to relay long sections of the track entirely with metal ties (utilizing the serviceable wooden ties for repairs elsewhere) is a very expensive method of working, for the following reasons: (1) The train service is seriously interfered with, and on sections where the traffic is heavy the repairs have often to be suspended temporarily until the block has been cleared off; (2) many wooden ties are damaged when drawing the spikes and by removing them with picks or crowbars; (3) numbers of wooden ties which would have lasted a year longer or more if left undisturbed find their way to the firewood yard instead of being put into the track again; (4) a large gang of men is required, and consequently there is a greater loss when, owing to unforeseen or unavoidable circumstances, any detention occurs. As above stated I can not agree with these opinions. The economy in renewals is exceptionally marked in India, as, for instance, the East Indian Railway reports the annual average percentage of renewals at 0.64 to 2.74 per cent for cast-iron ties and 5.28 to 5.98 per cent for wood, while on the Eastern Bengal Railway the average is only 0.06 per cent per annum. With nearly all the modern steel cross-ties the renewals have been greatly reduced. Many of the steel ties which have been tried would have given much better results had they been made of heavier metal. To attempt to bring the first cost of a metal tie so low that it can be supplied as cheaply as a wooden tie is unwise in the extreme, and unless metal is very cheap and wood very dear this can only be done by sacrificing efficiency and involving future expense. Metal ties of good pattern have so much longer life than wooden ties that it is not necessary to limit their cost to such an extent as is attempted by some inventors. It is also of importance that the ties should be of such form that one can be removed or renewed without interfering with the passing of trains or disturbing the road on either side. Some of the ties patented can only be slipped on at the end of the rail, and if a tie in the center of a rail required renewing two pairs of joint plates and all the ballast would have to be removed, and the rails slewed six inches out of line; after which all the ties between the end of the rail and the damaged tie would have to be taken off before the repairs could be effected. With other types the rail has to be sprung with crowbars in order to get the flange under the clips, but although simplicity and a minimum number of loose parts may both be classed as advantages, it is possible to overdo each of them and thus sacrifice efficiency and economy. In both these cases the track would be disturbed to an unnecessary and expensive extent.

Experienced trackmen are not always available, and as a great portion of the relaying and construction work is likely to be done by men who have been imperfectly trained, any metal tie that requires more than the ordinary amount of care, or is in any way complicated, is more likely to come to grief than if it were of simpler construction and able to stand rough usage. It is, however, of importance that renewals (and track laying) should be done by intelligent men under careful supervision, as already noted.

MAINTENANCE.

In this respect, as in renewals, there may be, and certainly should be, a marked economy, but a consideration of the individual statements in Part I show very diverse experience and opinions. The general tenor of the opinions, however, seems to be that after about two or three years the cost for maintenance becomes rapidly less than a track with wooden ties, and this is what might be reasonably expected. Some railways report a marked saving (especially after two or three years), others report very little difference, while a few report increased cost. The cost, however, depends very largely upon the style of track, type of tie, extent of traffic, etc. It must also be remembered that most of the European and many of the other comparisons of cost of maintenance refer to treated wooden ties of long life, and not to the short-lived ties common in this country. Then again the records and statistics are not based upon any uniform system, so that the results can really not be compared with any expectation of accurate comparison. The Belgian state railways report very unsatisfactory results in this respect, but the accuracy of the calculations has been called in question, and very much better results have been reported from other roads. (*See* Austria and France, especially). The New York Central Railway has had excellent results from the 800 steel ties laid in 1889.

From the statements accompanying the report on the maintenance expenses of track on wooden and on metal ties, presented at the meeting of the International Railway Congress in 1892, the following figures are taken: State railways of France, 12,24, and 41 per cent less than wood for the years 1887-'88-'89, the average being 24 per cent; Jura, Bern, Lucerne Railway (now Jura-Simplon), 206 days per mile per year for wood and 129 with metal. The Paris, Lyons and Mediterranean Railway found on its Algerian lines a saving of 26 per cent by the use of metal ties. On these lines wooden ties costing $1.40 each last ten years and cost for maintenance $235 per mile per year. The metal ties cost $1.75, last thirty years, and only cost about $154.50 per mile per year. The Great Central Railway, Belgium, reported an average cost of $161.88 per mile per year for track on wooden ties (including rail and tie renewals) and $20 for metal ties.

> This latter figure is the average of expenses during the years 1886 to 1890, inclusive; it is extremely low, because, up to this time, the tamping and dressing are perfectly well maintained, and there have been no renewals of rails, ties, or accessories.

Mr. Kowalski remarked on this point that $20 per mile per year represented twenty to thirty days' labor of 1 man per year; that is to say, that a floating gang of 5 men would suffice to attend not only to the maintenance but to the special supervision of a section 31 miles long. This is in proof of the opinion he has always held, that a track on metal ties, when once well settled, does not require maintenance in the way of lining and surfacing, thus effecting a saving in the number of men and in the amount of ballast. He estimated that the saving amounted to 12 per cent for the first year, and gradually increased to 30 or 40 per cent.

ECONOMY.

The economy effected by the use of metal ties is due not only to the greater life of the tie, and consequent reduction in renewals, but also to the reduction in cost of labor in renewing ties and putting the track in condition. As the ballast and track, once disturbed, takes some time to become consolidated again, there is a further saving in the extra cost of maintenance which is directly traceable to the renewals of wooden ties. This economy has been found on the New York Central Railway and many foreign railways. In 1894 the chief engineer of the Southern Mahratta Railway, of India, made a report to the government on steel, cast iron, and teak ties. He considered the steel greatly superior to the wood, but the cast iron even more durable than the steel, and as the value of the old cast iron is about 75 per cent of the original value it was concluded that on the whole the cast iron ties were the most economical.

COST.

The prices of metal ties in other countries afford little basis for estimating the cost in this country, owing to the difference in labor conditions and in the prices for materials and labor. Some European engineers of experience estimate that a metal tie should cost not more than 1.6 to 2 times as much as a wooden tie in order to effect a decided economy in maintenance and renewals. This, however, is based upon a life of 15 years for the wooden and 30 years for the metal ties, and a large increase in cost would be admissible where the wooden ties have a life of only 7 to 10 years. None of the metal ties yet manufactured in this country have been made on a sufficient scale to enable a market price to be determined, as a special expenditure for plant is required. At present ties suitable for main-track service could probably not be furnished for much less than $2 market value. The New York Central Railway's new 100-pound ties cost $2.50 each, but the makers estimate that in quantities and at the present price of steel they could be furnished for less than $2. The Daniels 60-pound tie for street-railway tracks costs about 67 cents, or 74 cents with fastenings complete.

I will say here in regard to metal ties what I have frequently said in regard to rails, namely, that it is a wise policy and good economy to pay a good price for a good article; or, in other words, to buy good materials and to pay what they are worth. If better prices had been paid for steel rails during the last ten years there would have been less complaint as to the quality and less trouble and expense in maintenance and renewals. The modern tendency to buy the cheapest material simply because it costs less is detrimental to good work and economy.

The following mathematical discussion of the question of cost of ties was prepared by Mr. B. E. Fernow. (*See also* paragraph on "Weight," in Part III.)

The item of cost is naturally of primary importance with good financiers, but for a perpetual concern like a railway the first cost is not always the most important factor of calculation. In fact, the saving of labor for renewals and maintenance is now the vital question in the cost of railway working. When this is brought to a minimum by perfection of road, then safety and comfort in traveling, as well as a dividend, will be secured.

According to Mr. C. P. Sandberg, who advocates only the most solid structure, the desirable metal tie may be said to cost as much per ton and weigh as much per mile of line as the rails themselves. Mr. Gustav Meyer, of the Prussian state railways, says that iron cross-ties of 110 pounds weight, costing $1.73 each, must last twenty-five years in order not to involve an annual charge of more than 9.8 cents, which is the average annual charge for wooden ties on German railways; but this charge is figured too low, and the metal tie, to be within the annual charge of 9.8 cents on the first cost alone, must not cost more than $1.40. (*See* table for computing annual charges, on following pages.)

To get at the annual cost for the provision and renewal of railway ties the following points must be considered:

(1) The annual interest on first cost.
(2) The annual sum laid aside for depreciation.
(3) The "old material value," lessening the amount of depreciation.
(4) Cost of labor and tools for replacing ties.
(5) Cost of the attachment to the rail.
(6) Cost of maintenance in the roadbed.
(7) Influence of tie upon the life of rolling stock.

The first cost of fastenings for wooden ties is less than for metal ones, but the cost of renewal is greater in the former case, so that in the end the annual cost for fastenings becomes less in the case of metal ties.

The cost of maintenance of a steel-tie track three and one-half years old was found the same as that of one of the same age laid on wooden ties, but from this point on the cost of the latter increases, while the cost of the former tends to diminish, owing to the consolidation of the bed. One of the district engineers of the Netherlands Railway states that on a test piece of 1,144 yards, on a curve of 820 yards radius and a grade of 1 in 83, no tamping of the ballast was required for 22 months ending December 31, 1884, and that the only maintenance required was one man for 34 days inspecting and tightening up bolts.

On the Rhenish roads, which at the end of 1879 had 112 miles of track laid with longitudinal and 197½ miles with cross metal ties, and to which, during 1880, were added 94 and 138 miles, respectively, the following results were obtained: On 100 miles of track with wooden ties 271 labor days were required yearly; with metal longitudinal system, on an average of three years, only 258, or 5 per cent less; and the average amount of labor expended in the year 1879 was only 209 days, or 23 per cent less; with iron cross-ties, during an average of 25½ months, 242 days, or 11 per cent less, and for the average of the year 1879, 164½ days, or 35 per cent less were required.

In Germany the cost of maintenance has been found to vary from $38 to $360 per mile with long-tie system, and from $47 to $107 with cross-ties, subsoil, bed material, and kind of structure causing great differences.

CALCULATING COMPARATIVE COST.

[Written by B. E. FERNOW.]

There appears to have been some difficulty experienced by engineers in coming to a conclusion as to how the cost of different systems, types, or processes ought to be compared, which vary as for instance in the case of ties in the initial cost in the number of years that they will last, and, in addition, in the frequency at which the expense of renewal recurs. The difficulty, it seems, need not exist at all, and can be removed by the application of simple mathematical formulas and mathematical deductions, and put into a form which will allow a ready comparison.

The simplest and most satisfactory way of comparing two systems is by taking recourse to a calculation of annual charges.

The expenditure R occurring now and recurring every n years, like that for the renewal of railroad ties, is changed into an annual charge r by the formula.*

$$r=\mathrm{R}\frac{1.0\,p^{n}\,0.0\,p}{1.0\,p^{n}-1}$$

in which p is the rate of interest and $1.0\,p=\frac{100+p}{100}$

This formula is found by summing up the recurring intermittent expenditures (R) discounted to the present time on one side and setting them equal to the sum of the discounted annual charges (r) on the other side:

$$\mathrm{R}+\frac{\mathrm{R}}{1.0\,p^{n}}+\frac{\mathrm{R}}{1.0\,p^{2n}}\ \ldots=\frac{r}{1.0\,p}+\frac{r}{1.0\,p^{2}}+\ \ldots\ \frac{r}{1.0\,p^{n}}$$

In the following, Table I, the fraction $\frac{1.0\,p^{n}\,0.0\,p}{1.0\,p^{n}-1}$ has been computed for rate of interest at 5 per cent, and for various terms of n.

By multiplying the fraction, given for 1 cent expenditure, under the

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[*] In the above formula the charge is conceived to be made for the end of the year Charging at the beginning of the year the formula is changed to $r=\frac{\mathrm{R}\,1.0\,p^{n-1}\,0.0\,p}{1.0\,p^{n}-1}$. To use the table for this formula it is only necessary to divide the figures with $1.0\,p$.

term in which the expenditure is to recur, with the actual amount of the expenditure in cents the annual charge is found.

This multiplication is carried out in the table for varying expenditures from 20 cents to 125 cents.

If a lower rate of interest is used in calculating the annual charges, these, to be sure, fall out lower, but the amounts of saving increase. So that it may be assumed that the table calculated upon a 5 per cent basis gives the most conservative, practically applicable results.

If the actual amount saved is to be determined, we need only find and compare the capitals which produce annually if placed on simple interest the amounts of the annual charge; or to arrive at the amount of that capital directly, we need only omit in the above formula the multiplication with $0.0p$.

If the expenditure is not now incurred, but becomes first necessary after n years and then recurs at intervals of n years, like the cost of replacing railroad ties (assuming that the first laying is done at a different figure), or allowance for the value of the old material, the formula for the annual charge is changed into

$$r = \frac{R \quad 0.0p}{1.0\,p^{n} - 1}$$

For this the needful computations are found in Table II.

The above formula applies no matter whether the number of periods of renewed expenditure is taken as infinite or as a finite business term.

Another way of comparing two systems for a given business term is to calculate the total capital value of the recurring expenditures with compound interest for the given term; thus:

R=amount paid out once in n years.
m=number of terms of n years.
V=total capital value of the expenditures at the end of m n years.
p =rate of interest; then

$$V = R\,\frac{(1.0\,p^{mn} - 1)\ 1.0\,p^{n}}{1.0\,p^{n} - 1}$$

If we consider two systems in which the corresponding values are $V_{,}$, $R_{,}$, $m_{,}$, $n_{,}$ and $V_{,,}$, $R_{,,}$, $m_{,,}$, $n_{,,}$, we have from (1)

$$V_{,} = \frac{R_{,}\ 1.0\,p^{n'}\,(1.0\,p^{m_{,}n_{,}} - 1)}{1.0\,p^{n_{,}} - 1}$$

$$V_{,,} = \frac{R_{,,}\ 1.0\,p^{n_{,,}}\,(1.0\,p^{m_{,,}n_{,,}} - 1)}{1.0\,p^{n_{,}} - 1} \quad . \quad . \quad . \quad . \quad (2)$$

Since for comparison we must have $m_{,}\,n_{,} = m_{,,}\,n_{,,}$, the values (2)give

$$\frac{V_{,}}{V_{,,}} = \frac{R_{,}\ 1.0\,p^{n_{,,}} - 1}{R_{,,}\ 1.0\,p^{n_{,}} - 1}\ 1.0\,p^{n_{,} - n_{,,}}$$

From this we see that the first or second system will be the more advantageous, according as $\frac{V_{,}}{V_{,,}}$ is less or greater than 1.

If, for instance, we introduce into these equations the following elements, in one case a tie costing 60 cents in the roadbed, lasting eight years, in the other case a tie costing the same but lasting sixteen years, 2,600 ties to the mile, we find for a term of thirty-two years, in the first case an expenditure of investment and accumulated interest of $18,131.18, and in the other case of $10,836.42, or, since

$$\frac{V_{//}}{V_{/}}=\frac{2,600 \times 60 \times 1.05^{8}-1 \times 1.05^{8}}{2,600 \times 60 \times 1.05^{16}-1}=0.60,$$

the saving of the longer-lived tie amounts to 40 per cent. By discounting the difference in accumulated expenditures after thirty-two years, namely, $7,294.76 to the present year, according to formula $E=\frac{A}{1.0p^{n}}$, we get the present capital saving, namely, $1,531.90. This represents the financial advantage of the tie of longer duration for a thirty-two year run. For a longer run this amount increases naturally.

Example.

Four systems are to be compared.

I. A metal tie system, requiring 2,000 ties per mile, the tie costing $2.40 to lay, lasting thirty-two years, and when taken out being worth 40 per cent of original cost or 80 cents.

II. A wooden tie system, requiring 2,700 ties per mile, the tie an oak tie costing 75 cents, to which 20 cents must be added for first laying and 15 cents for renewals, the tie lasting eight years, and when taken out being worth 10 per cent or 7.5 cents.

III. A wooden system of 3,000 ties, hemlock, ties costing 40 cents in the roadbed and lasting four years, without value when taken out.

IV. Hemlock tie system, with 2,700 ties, impregnated, at a cost of 20 cents per tie, and protected by a metal tie plate costing 30 cents per pair, and being worth 3 cents as old scrap at the end of twelve years, when the tie is taken out of service.

I. Metal tie:

Annual charge on $2.40 for thirty-two years period	$15.12
Less annual charge for return of 80 cents after thirty-two years	1.04
	14.08
For 2,000 ties	281.60

II. Oak tie:

Annual charge on 75+20=95 cents for eight years period	14.70
Add annual charge for renewals at 15 cents	.70
	15.40
Less annual charge for return of 7.5 cents every eight years	.68
	14.72
For 2,700 ties	397.44

III. Hemlock tie:	
Annual charge on 40 cents for period of four years	$11.28
For 3,000 ties	338.40
IV. Hemlock tie, treated, and with tie plate:	
Annual charge on 40+20+30=70 cents for period of twelve years	7.82
Less annual charge on return of 3 cents every twelve years	.19
	6.63
For 2,700 ties	206.00

Showing, as far as actual cost of the systems is concerned, outside of maintenance expenses, the treated hemlock tie, with tie plate, under the conditions assumed, the cheapest by from one to two-thirds, and the metal system next, but even at a cost of $2 per tie, 60 per cent cheaper than the oak.

AMORTIZATION TABLES.

TABLE I.—*For computing annual charge of initial expenditures.*

Expenditure.	Term of years.																		
	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1 cent	0.282	0.211	0.197	0.173	0.155	0.140	0.129	0.120	0.112	0.106	0.101	0.092	0.085	0.080	0 076	0.072	0.069	0.067	0.065
20 cents	5.64	4.62	3.94	3.45	3.10	2.81	2.59	2.40	2.24	2.13	2.02	1.84	1.71	1.60	1.52	1.45	1.39	1.34	1.30
25 cents	7.05	5.77	4.93	4.32	3.87	3.52	3.23	3.00	2.80	2.66	2.53	2.31	2.14	2.00	1.89	1.81	1.73	1.67	1.62
30 cents	8 46	6.93	5.91	5.18	4.64	4.22	3.89	3.61	3.38	3.19	3.03	2.76	2.56	2.40	2.27	2.17	2.08	2.01	1.95
35 cents	9 87	8.08	6.89	6.04	5.41	4.92	4.58	4.21	3.93	3.72	3.53	3.22	2.99	2.80	2.65	2.53	2.43	2.34	2.27
40 cents	11.28	9.23	7.88	6.90	6.19	5.62	5.18	4.81	4.49	4.25	4.04	3.69	3.42	3.20	3.03	2.89	2.78	2.68	2.60
45 cents	12.69	10.39	8.86	7.76	6.96	6.32	5.82	5.41	5.04	4.78	4.54	4.15	3.84	3.61	3.41	3.26	3.12	3.01	2.92
50 cents	14.10	11.54	9.85	8.63	7.74	7.03	6.47	6.01	5.60	5.32	5.05	4.61	4.27	4.01	3.79	3.62	3.47	3.34	3.25
55 cents	15.51	12.70	10.84	9.49	8.51	7.73	7.12	6.61	6.15	5.85	5.55	5.07	4.70	4.41	4.17	3.98	3.82	3.68	3.57
60 cents	16.91	13.85	11.82	10.35	9.28	8.43	7.72	7.21	6.71	6.38	6.06	5.53	5.12	4.81	4.55	4.34	4.16	4.01	3.90
65 cents	18.32	15.00	12.81	11.22	10.06	9.14	8.41	7.81	7.26	6.91	6.56	5.99	5.55	5.21	5.93	4.70	4.51	4.35	4.22
70 cents	19.73	16.16	13.79	12.08	10.83	9.84	9.06	8.41	7.82	7.44	7.07	6.45	5.98	5.61	5.31	5.07	4.86	4.68	4.55
75 cents	21.14	17.31	14.78	12.94	11.61	10.54	9.71	9.01	8.37	7.98	7.57	6.91	6.41	6.01	5.69	5.43	5.21	5.02	4.87
80 cents	22.55	18.47	15.76	13.81	12.38	11.25	10.36	9.62	8.93	8.51	8.08	7.37	6.83	6.41	6.06	5.79	5.55	5.35	5.20
85 cents	23.96	19.62	16.75	14.67	13.15	11.95	11.00	10.22	9.48	9.04	8.58	7.83	7.26	6.81	6.44	6.15	5.90	5.69	5.12
90 cents	25.37	20.97	17.73	15.53	13.93	12.65	11.65	10.82	10.04	9.57	9.09	8.30	7.69	7.21	6.82	6.51	6.25	6.02	5.85
95 cents	26.78	21.93	18.72	16.39	14.70	13.35	12.30	11.42	10.59	10.10	9.59	8.76	8.12	7.62	7.20	6.89	6.59	6.36	6.17
100 cents	28.20	23.08	19.70	17.26	15.48	14.06	12.95	12.02	11.15	10.64	10.10	9.22	8.54	8.02	7.58	7.25	6.94	6.69	6.50
105 cents	29.61	24.24	20.69	18.12	16.25	14.76	13.59	12.62	11.70	11.17	10.60	9.68	8.97	8.42	7.96	7.61	7.29	7.03	6.82
110 cents	31.02	25.39	21.67	18.98	17.02	15.46	14.24	13.22	12.26	11.70	11.11	10.14	9.40	8.82	8.34	7.97	7.63	7.36	7.15
115 cents	32.43	26.54	22.66	19.85	17.80	16.17	14.89	13.82	12.81	12.23	11.61	10.60	9.82	9.22	8.72	8.38	7.98	7.70	7.47
120 cents	33.84	27.70	23.64	20.71	18.57	16.87	15.53	14.42	13.37	12.76	12.12	11.06	10.25	9.62	9.10	8.70	8.33	8.03	7.80
125 cents	35.26	28.85	24.63	21.57	19.35	17.57	16.18	15.02	13.92	13.30	12.62	11.52	20.68	10.02	9.48	9.06	8.68	8.37	8.12
Add for each additional 5 cts.	1.410	1.154	0.985	0.863	0.774	0.703	0.647	0.601	0.560	0.532	0.505	0.461	0.427	0.401	0.379	0.362	0.347	0.334	0.325

TABLE II.—*For computing annual charge of renewal.*

Expenditure.	Term of years.																		
	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1 cent	0.317	0.232	0.181	0.147	0.123	0.105	0.09	0.079	0.07	0.063	0.051	0.042	0.039	0.03	0.026	0.023	0.019	0.017	0.015
10 cents	3.17	2 32	1.81	1.47	1.23	1.05	0.90	0.79	0.70	0.63	0.51	0.42	0.39	0.30	0.26	0.23	0.19	0.17	0.15
12 cents	3.80	2.78	2.17	1.76	1.48	1.26	1.08	0.95	0.84	0.76	0.61	0.50	0.47	0.36	0.312	0.28	0.23	0.20	0.18
15 cents	4.76	3.48	2.72	2.21	1.85	1.58	1.35	1.19	1.05	0.95	0.77	0.63	0.59	0.45	0.39	0.35	0.29	0.26	0.24
20 cents	6.34	4.64	3.62	2.94	2.26	2.10	1.80	1.58	1.40	1.26	1.02	0.84	0.78	0.60	0.52	0.46	0.38	0.34	0.30

FROGS AND SWITCHES.

A defect of a large proportion of metal track systems is that they can not be used at frogs and switches, owing to the inability to adjust fastenings to suit the varying positions of the lead rails, or to attach the frog, switch points, and guard rails. Metal ties offer the particular advantage of giving increased safety, smaller cost of maintenance, and a smooth riding track for switches and turnouts; and if metal ties are used at all, it is most desirable that they should be applicable at such situations, not only for the above reasons, but also to insure a uniform and continuous type of track. The Austrian State Railways use the Heindl ties very extensively, and the Gotthard Railway uses its trough ties, for though the latter cost about twice as much as oak switch ties, the rest of the expense remains about the same. The Porto Rico railways use the Boyenval-Ponsard steel ties and find them entirely satisfactory. With bolt fastenings additional holes may be drilled in the tie while in the track. In this country a modified form of the Standard tie has been designed, in which the rails and fastenings on each tie can be adjusted to any position. This offers an advantage over the other systems mentioned above in track laying and renewals, as it is not necessary to have the ties in a certain order. All ties of equal length (the switch ties being in sets of extra lengths) are interchangeable, while ties with bolt holes must be placed in consecutive order to give the proper position to the lead rails. (See U. S. patent, No. 517915.) With the Hohenegger longitudinal system (Northwestern Railway, Austria) the turnouts and crossovers are laid on wooden cross ties, but the switch rails rest on the metal longitudinals.

RECORDS.

The desirability of keeping careful records of the laying and renewals of ties, cost of work, and amount of traffic, etc., has been pointed out in my former report; but attention should be called to the fact that the life should be determined by the number of trains and the load sustained rather than by the mere number of years during which the ties remain in the track. Some roads, desiring to effect economy in renewals of wooden ties, mark the ties, in some way to indicate the year in which they were laid, so that their length of service can be at once determined, and some such plan should be followed with metal ties. For the records to be of any use it is absolutely necessary that they should include statistics of the climate and atmosphere, the character of soil and ballast, the number, weight, and speed of trains, etc. They should also be kept regularly and completely, and the results analyzed and studied from time to time.

Mr. Cole, in a short paper presented to the Institution of Civil Engineers, England, in 1894 (Proceedings, Vol. CXVII, 1893–'94, Part III), pointed out that the average life of rails and ties is frequently recorded without any details as to soil, hygrometric, or other atmospheric conditions, train loads and speeds, grades, etc., and no practical deductions can possibly be made from such incomplete statistics. The arithmetical calculations may be fairly accurate, but a few miles of steel track laid in a wet saline soil will completely spoil the average. The following known facts must be taken into account in considerations regarding Indian railways: (1) It is known that wooden ties are rapidly attacked by white ants in certain districts, and steel ties are rapidly rusted or corroded in other districts; (2) at certain points in the railway system deodar ties from the Himalayas, creosoted pine ties from Europe, and steel or cast-iron ties from England, meet in regard to cost; (3) any attempt to fix an artificial price on indigenous wooden ties can be foiled by a recourse to imported metal ties; (4) the longer life of metal ties under well-known conditions will compensate for their greater cost; (5) the cost and life of the fastenings required with each description of tie must be taken into account; (6) old wood and cast-iron scrap have a varying value in different parts of the country, but while old cast-iron ties are eagerly bought for scrap, unserviceable steel ties have little or no value. In regard to the half-yearly official figures of tie renewals, etc., it was remarked in "Indian Engineering" that the elaborate statistics as to ties given in the half-yearly "Analysis of Working" are of very little practical use. If certain lengths of cast-iron bowl ties, Denham-Olpherts cast-iron plate ties, steel ties, deodar and other wooden ties, etc., could be laid in several parts of the country so that they might be exposed to very different conditions, which would be carefully noted, it would be known each year how many of each survived and the particulars of their behavior under various conditions of ballast, climate, traffic, etc., could be definitely ascertained. But without such details little or nothing of practical value can be deduced from the figures given in the administration reports.

RACK RAILWAYS.

A number of short railways operated on the rack-rail system have been built in Europe during the last few years, generally for passenger or excursion traffic only, and in most cases steel cross-ties are used, as they allow of a better and more secure attachment of the rack and rails. The Barmen Mountain Railway (*see* Germany); the Monte Generoso Railway, and Brienz and Rothhorn Railway (*see* Switzerland), and the Bosnia and Venezuela rack railways are examples of this type of railway. The Mount Washington Railway and Pike's Peak Railway, in this country, and the Nilgiri Railway, in India, use wooden ties.

PIONEER RAILWAYS.

It is worthy of note that while heavy metal ties are being used on railways with heavy traffic, lighter ties are being extensively used for pioneer railways, such for instance as the Normanton and Croydon Railway of Australia, and the Congo, Beira and Mombasa railways of Africa.

LIGHT RAILWAYS.

Even in the more thickly settled countries metal ties are used for light railways of practically the same type of construction as the pioneer railways above referred to. Such, for instance, are the Charleroi local railways, Belgium; the Bengal Provincial Railway, India, and other secondary lines and steam tramways.

TIES OF OLD RAILS.

Designs for the utilization of old track rails in making steel ties are very little heard of now. In the first place, they can not be expected to make really good ties, owing to lack of uniformity of wear and conditions; and in the second place, their manufacture would usually involve an amount of shop work and fitting that is apt to be overlooked in the claims for the economy of such ties. The Taviers and Embresin Railway, Belgium, uses ties of old rails, as already described. The Los Angeles Consolidated Electric Railway has also used steel ties, as noted further on in regard to "street railways." The Cannon tie is designed to utilize old rails, and the Daniels ties are made from old rails, but in the latter case the rails are rolled into corrugated plates and not used in their original form. Particulars of American inventions in this direction are given in the summary of patents at the end of Appendix No. 2. It is possible that a cheap and light form of tie suitable for colliery and mine tracks may be made from old rails, as instanced by the White tie (England).

Another proposition for the use of waste material in the construction of steel ties is to cut old steel rails (Vignoles or T section) into lengths of 7 feet 10 inches and rivet them to cast-iron chairs (those used with Vignoles rails), two lengths to each pair of chairs, thus forming a cheap, strong, and durable tie, which will be worth as much as new ties would be after both have served their turn, while at the same time using what is now a drug in the market.—(*B. E. Fernow, Bulletin No. 1, 1887.*)

COMPOUND TIES.

Various designs have been made for compound or combination ties made of wood and iron, but they are not promising, owing to the trouble of manufacture and the liability of the parts to get loose. (*See* summary at end of Appendix No. 2.)

As the object of these notes is to point out where a saving in the use of wooden material for railway construction may be effected, the following suggestion may find proper place here, describing a system of using up old wooden ties practiced on the Netherlands State railways.

The best wooden ties fail at the point where the rail rests on the tie, while a length of from 3 to 3½ feet between the rails remains quite solid. Laying two such lengths, sawed off end to end, they are joined together by a length of inverted channel iron let into the timber, so that its web lies upon the upper surface. The rail rests on the channel iron, which thus prevents it from wearing into the tie. (By bending, the 1-in-20 cant, if required, can be given.) The sawing, dressing, boring, and putting together of these compound wooden and iron ties can be done in wet weather by the trackmen, thus saving in the cost. The laying and tamping are the same as with ordinary ties. As these compound ties have four end-faces, they offer increased resistance to lateral motion.

In July, 1882, a quantity of these ties were laid in a main line through a station, and in September of the same year a further number on a main line curve of 50 chains radius and a gradient of 1 in 62, over which ran thirty trains a day, some of them expresses. Both of these lengths have required no different treatment from the adjoining lengths laid with ordinary wood ties, while the gauge has remained exactly true.

In a similar manner may be joined together short metal waste pieces which are left in making steel ties, in order to reduce the price of the perfect steel tie, the waste pieces being riveted together. This attempt to produce a cheap steel tie, at least for secondary lines, may be considered quite successful. The Netherlands State railway, in June, 1885, laid a number of such ties on a curve of 26 chains radius with a gradient of 1 in 62. These ties have shown no disadvantages during loading, unloading, laying, or tamping, and have required no more tamping than ordinary ties near them. There are six different types of these riveted ties, in all of which the rivets are 0.79 inch diameter. The joint may be 6 inches from the center of the tie, so as to allow of short pieces being used up.

The newest proposition is, for the sake of cheapening iron ties, to employ soft cast iron, avoiding the expense of rolling, or, rather, for the same price to give more material and more weight to the tie. Such ties are made at Halbergerhütte, near Saarbrücken, Germany, and are capable of being deflected (slightly) without breaking, and are tough enough not to break on being dropped by the men handling them. They cost $1.60 per tie and weigh 220 pounds, instead of 110 pounds, the weight of the Haarmann tie.

To obviate the objection of danger from spreading of gauge, the writer proposes to combine with this cast iron tie a wooden one, for the purpose simply of holding in place bolts or spikes and preventing the spreading. The wooden ties thus used are only one-third of the thickness of those now in use, allowing a saving of material. Longer bolts or spikes (by the thickness of the iron tie) are to be used. The additional cost of this construction, taking original wooden ties at $1.20 (now $\frac{1}{3} = 40$ cents) and ten ties for 100 feet of rail, gives $\frac{10}{30} - 5280 \times 40$ cents = $7.04 increased cost ($\frac{10}{9}$ a mile).—(*B. E. Fernow, Bulletin No. 1, 1887.*)

STREET RAILWAYS.

In this country wooden ties and stringers, or longitudinals, are commonly used in street railway track, and being bedded in the earth decay rapidly, unless treated by some preservative process, but treated timber, however is comparatively little used for such work. See Kyanizing, Part III. Such construction is often followed, even on new city lines with heavy traffic and heavy electric cars, and of course a bad track is the inevitable result, the ties having no better foundation than the loose earth. For cable railways concrete and iron are universally used, and high-girder rails on concrete are used to some extent (as at Toronto, Canada), in accordance with English practice. It is satisfactory to note that the Daniels Steel Railway Tie Company is making a specialty of corrugated ties for street railways, and reported in July, 1894, an order of 4,000 ties for a line at Terre Haute, Ind. The ties weigh about 66 pounds each, and cost 66 cents each, or 74 cents, including the bolts, nuts, and clamps. The Charleroi local railways, Belgium, and the Barmen Mountain Railway, Germany, are laid partly in paved streets. Ordinary T rails on steel trough cross-ties are found very satisfactory in macadamized roads. The Budapest (Austria) tramways use the Demerbe track, the rails being of saddle or trough section, of different weights. The larger are 5 inches wide on top (with the top grooved), 7 inches wide over the bottom, and 6 inches deep, the thickness varying from seven-eighths inch at the tread and 0.56 inch at the groove, to 0.36 and 0.32 inch at the sides. At joints the rails are keyed to a short piece of saddle form fitting inside the rail ends, and tie-bars are placed at intervals. The rails are filled and tamped with sand or gravel, and a stone-filled trench is constructed under each line of rails. The same system is used in macadamized roads in Cologne.

Metal ties are but little used for street railway tracks in this country. On the Los Angeles Consolidated Electric Railway old T rails have been used as ties. The track is 3 feet 6 inches gauge, and the ties are about 4 feet 4 inches long. Each tie consists of a piece of T rail, head downward, and to one side of the flange (resting on the flat base of the rail) are riveted two Z-iron chairs 4 inches high, 6 inches long, with flanges 3 inches wide. Each chair is fastened by three rivets. Upon the top flange of each chair rests the side-bearing girder track rail, secured by two hook bolts, with nuts under the chair flange. Grout is tamped in around the rail to the level of the head and tread, and a row of granite blocks laid on each side of each rail. The track and bituminous rock paving rest upon 6 inches of concrete, and each tie is in a trench 18 inches deep and 6 inches wide, filled and rammed with concrete. At rail joints two ties are placed about 4 inches apart, and the trench is 12 inches wide. In 1887 the Des Moines Street Railway Company had laid 1,000 metal ties made by the Johnson Company, costing three times as much as oak ties. They weighed 30 to 40 pounds, cost $1.25 each, and had riveted and bolted clamp fastenings for the rails. The paving was of cedar block on plank flooring. The Johnson Company rolled a metal tie section in 1890, but could not introduce it, as the ties cost $1.25 each, and were really not as serviceable as wooden ties. It has therefore abandoned their manufacture, considering them at present impracticable. Mr. George B. Hippee, general manager of the Des Moines City Railway Company, stated in September, 1894, that the ties above mentioned were laid on a narrow-gauge track, and when the gauge was changed and electric traction introduced the ties were taken up and disposed of as scrap. They gave good service while in use under light horse-car traffic, but it is not known how they would have done for the heavy electric cars. In August, 1894, the Indianapolis Street Railway Company placed an order for 4,000 of the Daniels steel ties. (*See* Part I, United States; *see* also the summary at end of Appendix 2.)

There is no doubt that the ordinary street railway track, like street paving, in this country is in general very inferior to European track, and this is a matter which might well be made the subject of investigation as to cost, efficiency, and durability, by the American Street Railway Association.

PORTABLE AND INDUSTRIAL RAILWAYS.

The use of light metal track in portable sections for use at mines, forests, plantations, construction works, etc., was noted in my original report, and the makers of this special class of railway material continue to do a good business. In addition to the makers of such material (with switches, cars, etc., and all appliances) noted in the original report, the following may be mentioned: Friedrich Krupp, of Essen, Germany; A. Legrand, of Mans, Belgium; Orenstein and Koppel, of Berlin and Cologne, Germany. The track is made of various gauges, and with various weights of rail, to accommodate the various purposes for which such railways are applicable. In this country portable railway track is but little used, probably the only places being on a few of the Louisiana sugar-cane plantations, some of the track being of the Decauville type (imported) and some made by the Colwell Iron Works, of New York. A somewhat similar type of track, not portable, however, but intended for factories, steel works, mills, coal yards, and boiler rooms, etc., is the Hunt track, made by the C. W. Hunt Co., of New York (*see* United States, Hunt ties). This is generally of 21-inch gauge, and consists of light T rails, riveted to shallow-trough steel ties. About 36 miles in all have been manufactured, and the same company manufactures the switches and turntables, cars of various forms, steam and electric locomotives, etc., required for equipping and operating the lines. A special peculiarity is the use of outside flanges on the wheels. Where bolts are used to hold the rail, the edge of the rail base should not bear against the neck of the bolt, as it is liable to wear and cut the neck. (*See* U. S. patents Nos. 426877, 430533, and 517369.)

CONCLUSIONS.

The various points connected with the discussion of this general subject have been already pretty fully dealt with, and it is hardly necessary to make any repetitions or further review here. The report certainly shows, however, that the introduction of steel ties is rapidly increasing, and has already taken effect on nearly 10 per cent of the total railway mileage of the world, or 20 per cent exclusive of the United States and Canada. Besides the importance of the matter from a railway point of view, it is also of great importance from a commercial and industrial point of view. In Belgium, Germany, France, and England the manufacture of steel ties is an important industry. One firm alone in England has turned out 130,000 tons (or 2,800,000 in number) of steel ties, and can turn out 10 meter-gauge steel ties per minute. It is to be hoped that industries of this kind may be developed in this country. The following general conclusions may therefore be presented:

1. Metal ties continue to be used very extensively and their use is being extended.

2. While various results are reported, the general opinion is favorable to the metal track.

3. The introduction of metal ties leads to an important growth in the iron and steel industries.

HISTORICAL NOTES.

(See plates No. 4 and 5.)

The history and development of metal track have been given in some detail in my original report, but without a chronological summary, and in order to make the report complete the following general statement has been appended.

LONGITUDINALS.

Barlow (Fig. 1).—The first attempt at a track composed entirely of metal was made by Mr. Barlow, in England, whose "saddle-back" rail, first brought out in 1849, was the first longitudinal invented. It was of approximately Λ section, with concave flaring sides, and was intended to do away with the use of sleepers and chairs altogether, the rail being laid directly upon and filled with the ballast, though in some cases occasional cross-ties of angle iron riveted to the bottom of the rail appear to have been tried. The bearing area on the ballast could no doubt be made sufficient to support the loads, but the rail was vertically weak, and, unless the ballast was kept absolutely tightly packed into it, the concave sides of the rail spread elastically, and by working in and out gradually displaced the ballast between and below them. The Demerbe track (*see* "Street Railways," on p. 200) is apparently a development of the Barlow rail, but of trapezoidal instead of triangular section, or rather having three sides instead of two.

Macdonnel (Fig. 2).—In 1853 Mr. Macdonnel first conceived the idea of separating the longitudinal from the rail, and his track (Fig. 2), was laid on the Bristol and Exeter Railway (now Great Western Railway), in England, in 1853, as noted in my former report. Mr. Charles Wood, in a paper presented before the Institute of Civil Engineers, England, stated that the track on wooden cross-ties required in 1861 an expenditure for new lines of $7,678 per mile. At the same time the estimated cost for the Macdonnel track was $5,262, and Mr. Wood, taking the prices of materials in 1881, estimated a probable cost at that time of $4,300 per mile.

Bridges-Adams (Fig. 3).—In 1853 M. W. Bridges-Adams, the English reinventor of the fish-plate joint (first invented in America), proposed to bolt the vertical webs of angle irons to the web of a double-headed rail, the horizontal flanges being level with the underside of the rail head and resting on the ballast, but this did not give satisfactory results. The rails were connected at intervals by tiebars. A somewhat similar system, however, with angle or channel irons attached to grooved girder rails, has been used on some German street railways.

HARTWICH (Figs. 4, 5, and 6).—In 1865 this system of deep girder or T rail (see pages 138 and 144 and plate No. 12 of original report) was experimented with on the Rhenish railways of Prussia. It was intended to do away with cross-ties or longitudinals, the rails being laid in the ballast and the gauge maintained by flat tiebars having the ends rounded and threaded for the nuts. To give the rail an inward inclination wedge-shaped plates were introduced between the nuts and the rail web. The joints were spliced by heavy angle bars and two rows of bolts. This track at first met with much favor, and in 1870 there were 112 miles in use, but it soon began to be abandoned, and in 1880 there were only 10 miles on main lines and 31 miles on secondary lines. On the Alsace-Lorraine railways (Fig. 4) the rail was 7.2 inches high, 4.8 inches wide, with joints spliced by angle bars 10 inches long, and two rows of bolts. The tie-rods were 1.04 inches diameter, 9.84 feet apart, and closer at the joints. On the Bavarian State Railways (Fig. 5) the rail was 6 inches high and 4.8 inches wide, with joints spliced as above, but having a base plate bolted under the rail ends. The tiebars were flat, with turned and threaded ends, and were spaced 9.08 feet apart, except at joints, where they were 2.29 feet apart. The rails were 29 feet long, weighing 58½ pounds per yard, while the track complete weighed 136.11 pounds per yard. The rails were very large, but difficulties of rolling did not permit the flange to be made wide enough to give the track a satisfactory bearing on the ballast, for which a width of 8 to 9 inches was considered necessary. Fig. 6 shows the system of drainage for these longitudinals, with continuous rubble drains connected by cross drains 16½ feet apart.

DAELEN (Fig. 7).—In 1866 Mr. Scheffler invented a longitudinal system composed of three parts, with a separate or removable rail head, and this was tried on the Brunswick railways, Germany. In 1867 Mr. Daelen modified this design and obtained a sufficiently strong longitudinal, consisting of a curved base plate, two longitudinal angle irons, and a dovetailed rail head. This met with little success, owing to the the cost of manufacture, the constant attention needed for tightening the bolts, and the necessity for bending the several pieces hot for all curves.

HILF (Figs. 8 and 9).—In 1867 Mr. Hilf first introduced his system of longitudinal, which, in the original form or types derived therefrom, has been extensively used in Germany. The original form had the section of an E laid sideways (ᗰ), the object of the central rib being to stiffen the top table under the rail, but it was soon evident that this rib prevented a uniform tamping of the ballast. The ordinary form of rail was also used in place of the 52½-pound rails used in the first experiments made on the line between Ems and Wiesbaden. On the Alsace-Lorraine railways the rails were 0.39-foot high and weighed 56.4 pounds per yard, while the longitudinals were 12 inches wide, 2.4 inches high, 24.6 feet long, and weighed 59 pounds per yard. These had no central rib. The rail joints were spliced by heavy angle bars, but those of the longitudinals were not spliced. The rails were fastened by bolted clamps. The gauge was maintained by angle-iron cross-ties 7½ feet long, weighing 26.2 pounds per yard, which were bolted to the rail flanges at intervals between the longitudinals. Round tie-rods were also used, with threaded ends passing through the webs of the rails and secured by nuts. These rods were spaced 12.3 feet, center to center.

RHENISH (Fig. 10).—The inconveniences experienced with the Hilf type led the engineers of the Rhenish railways (now the Cologne division of the Prussian state railways) to devise a new type of longitudinal, of inverted trough section, with the bottom edges thickened to form stiffening ribs. They were 24.6 feet long, 0.65 foot wide on top, 0.98 foot wide on the bottom, and 0.29 foot high, weighing 72.6 pounds per yard. The rails weighed 60½ pounds per yard and were connected by transverse tie-rods or gauge rods. The joints of the longitudinal saddle plates, 2.3 feet long, of trough section, were fitted inside and secured by the same bolts which held the rail clamps.

HOHENEGGER (Figs. 11 and 12).—In 1876 Mr. Hohenegger introduced on the Northwestern Railway of Austria longitudinals which, like the Rhenish, were modifications of the Hilf type. The first pattern (Fig. 11) very closely resembled the Rhenish, but this was soon changed to conform more nearly to the original Hilf section. The rails weighed 60 pounds per yard, and were attached by bolted clamps, as described in detail in Part No. I (Austria). The longitudinals were 29.4 feet long, 0.98 and 0.55 foot wide, 0.24 foot high, and weighed 58.8 pounds per yard. The joints of rails and longitudinals coincide. The former are spliced by outside angle bars and inside fish plates. The latter are spliced by saddle plates 1.37 feet long, conforming to the interior of the longitudinal, and these are secured to a transverse angle iron (which holds the rails to gauge) and to the top of the longitudinal by the rail bolts.

HEUSINGER VON WALDEGG (Fig. 13).—This system, which was tried in Germany, aimed at the elimination of all bolts. The rails were of bridge section, fitting over a rib on the top of the longitudinals, and were secured by taper keys or wedges driven between each side of the rail and a loose jaw whose lower end fitted into a hole in the longitudinal. At the joints flat plates were bolted under the flanges of the longitudinals.

HAARMANN (Figs. 14 and 15).—Mr. Haarmann's first longitudinal, used on the Right Bank of the Rhine Railway (Cologne division, Prussian state railways), had ridges along the top edges, forming a shallow groove to receive the base of the rail. It was 12 inches wide on top, and weighed 47.4 pounds per yard. The rail attachment consisted of two clamps of channel shape, the top flange bearing on the rail base and the bottom flange on the inside of the longitudinals. The clamps were held together by a horizontal bolt passing through the longitudinal.

Mr. Haarmann also designed a compound rail and longitudinal combined (Fig. 15), being an adaptation of the Hartwich type. It was composed of two separate parts, each representing the half of a T rail, 0.65 foot high and 0.98 foot wide, weighing about 175 pounds per yard. The web of one half had a groove fitting a rib on the other half, to insure accuracy in putting them together, and to make them act together under loads. Flat iron tie bars were used to maintain the gauge, and the two parts are laid to break joint.

SERRES AND BATTIG.—This system of longitudinals was on the principle of the Scheffler and Daelen systems, above described, and was first used on the Austrian state railways in 1877, as described in my original report. (Pl. II and p. 155.)

MISCELLANEOUS.—A system invented by Mr. Kirsh, and said to have been very complicated and expensive, was tried some years ago on the Great Central Railway of Belgium. A system invented by Dr. Winkler, and tried on the Right Bank of the Rhine Railway, was similar to the Hartwich type, but had a renewable head.

PLATES AND BOWLS.

LIVESEY (Fig. 16).—Mr. James Livesey is said to have first introduced ties made of separate plates connected by tie bars, and two forms, used in Egypt and India, were shown on Pls. 17 and 20 of the original report, while a form somewhat similar to the latter and tried on the Great Eastern Railway (England) is shown herewith in Fig. 16. The plate is of sheet steel.

CROSS-TIES.

The first trial of metal cross-ties was made by Mr. LeCrenier, in 1860, with a tie of U-section, 7.87 feet long and 0.82 foot wide, weighing 51.7 pounds, to which the T-rails were attached by bolted clamps. In 1862 the Couillet Iron Works, of Belgium, tried similar ties, weighing about 100 pounds and having bearing plates or cushions of wood under the rails. Both of these types were adapted only to the T-rail, but about the same time an experiment with a tie for double-headed rails was made by Mr. Osborne Reynolds, of England. He proposed to cast the chair on the tie, making openings in the latter to allow the cast iron to flow under the top table. The manufacture presented many difficulties, however, and was abandoned; but the plan has been revived recently on the Western Railway of France, as recorded in Part I.

LEGRAND (Figs. 17 and 18).—In 1863 Mr. Legrand used a rolled tie of trough section with horizontal bottom flanges and two clamps riveted to the top. Alternate ties had the clamps fitting the outside of the rail, and the others had them fitting the inside. In tracklaying the ties with outside clamps were first laid and the rails placed upon them. The alternate ties with inside clamps were then put in position at such an angle as to allow of the clamps fitting over the rail flange, and these were then brought square across the track by heavy blows. Such a system, while practicable for light tracks, as in mines, etc., is objectionable for main tracks.

VAUTHERIN (Figs. 19 to 27).—In 1864 Mr. Vautherin invented the tie which is generally known by his name, and which has been the basis of numerous patented and unpatented designs of ties. The first trials, on the Northern Railway and Paris, Lyons and Mediterranean Railway, France, did not give very satisfactory results and a series of modifications followed. On the Alsace-Lorraine railways (Figs. 19, 20) the tie had the edges strengthened by ribs, which did not interfere with tamping. The rails were fastened by bolted clamps, and the inward inclination of 1 in 20 was given by bending the tie on a templet to a radius of 3,280 feet. On the Main-Neckar Railway the original form of the tie was used (Figs. 21, 22, 23), with horizontal lower flanges, which proved to make track laying, ballasting, and tamping difficult. The tie was there called the "Rhenish" type. The rails were fastened by bolted clamps, and the rail seats were inclined 1 in 20, in what is known as the Hosch-Lichthammer method. The form adopted in 1867 is shown in Fig. 24. The Paris, Lyons and Mediterranean Railway laid the original form of Vautherin tie in 1867 on the line from Oran to Algiers, which forms a part of its Algerian system. The ties (Fig. 25) were 7.87 feet long, 0.85 foot wide on the bottom, 0.26 foot wide on top (0.42 foot for joint ties), 0.33 foot deep, and 0.28 inch thick at the top table. They weighed 77 pounds each and were spaced 3.28 feet apart. The rails were of T section, fastened by jibs and cotters, as shown on Plate No. 17 of original report. The 5,000 ties laid in 1867 on the Northern Railway of France proved unsatisfactory, and it was said that there were too many parts, and that the ties had not sufficient anchorage in the ballast. On the Holland Railway an inclined tie plate was placed under each rail and secured by the rail attachment bolts (Fig. 26). On the Würtemberg Railway the upper table of the tie was thickened, so as to give a better hold to the rail fastenings, as shown in fig. 27. They were also used in Belgium and on the Alsace-Lorraine railways.

BERG AND MARCHE (Figs. 28, 29, 30).—This was tried first on the Berg and Marche Railway (now the Elberfeld division of the Prussian state railways), 664 ties being laid in 1867, by Mr. Jungbecker, engineer of maintenance of way. They were 7.2 feet long, weighing 62.7 pounds each, and were laid 2 feet apart in well-drained sand ballast. The rails were attached by gibs and cotters. During the first three years the track was good and easy riding, and the maintenance was as easy and cost about the same as on ordinary track, but after that time the holes for the rail attachments became enlarged, cracks occurred, and the experiment was abandoned. In 1874 a more important experiment was made in the Ruhr Valley, 25,000 ties, somewhat stronger than the above, being laid in a ballast composed of flint mixed with clay. Some of them were on a steep grade and others on a curve of 1,312 feet radius. These ties were selected after unsatisfactory experience with the original form of Vautherin ties. From the first year, in spite of the care with the attachments, the holes became enlarged, but this trouble was obviated later by the use of steel instead of iron for the ties. These ties have been in use on the Hesse-Louis, Baden, and Prussian state railways in Germany and on the Western, the Simplon, the St. Gothard, and the Northeastern railways of Switzerland. On the Hesse-Louis line (Fig. 30) the gauge is adjusted by means of eccentric shoulders on the bolts, while on the Baden lines this was effected by means of a special plate or washer. The inward inclination of the rail was given by curving the tie or by bending the ends.

MENANS (Fig. 31).—About half a mile of track between Byans and Torpes, on the Paris, Lyons and Mediterranean Railway (France) was laid with these ties from 1864 to 1872.

PARIS, LYONS AND MEDITERRANEAN RAILWAY (Fig. 32).—The tie of type A, Fig. 32, was in use from 1867 to 1869 between Maisons-Alfort and Villeneuve-St. George, and between Malains and Velars, but the results were far from satisfactory. The fastenings worked loose, the ties cracked in the angle at the right of the rivets which fastened the chairs, and the joint ties broke above the angle iron, which was intended to strengthen the tie. The type B, which differed from A only in the rail fastenings, was tried on the Grasse branch for eight or nine months in 1871–'72, but the results were not satisfactory, the fastenings being too weak.

BRUNON (Fig. 33).—This steel tie (page 92 of original report) was put down between Rive-de-Gier and Lorette, on the Paris, Lyons and Mediterranean Railway, but the experiment only continued from August, 1877, to September, 1878, in consequence of numerous fractures which occurred at the rail seats.

WOOD (Fig. 34).—These trough ties, with key and clamp fastenings, as used on the Northeastern Railway, England, were 8.4 feet long, 0.92 foot wide over the bottom, with a uniform thickness of 0.4 inch. The clamps are 2¼ inches wide, and are 0.52 inch thick where the jaw grips the rail flange.

HAARMANN (Figs. 35, 36, 37).—This tie comes next in order of date, and was used on the right-bank and left-bank railways of the Rhine, and in Alsace-Lorraine. The section is similar to the Haarmann longitudinal, but the fastenings are vertical bolts. On the left-bank (Rhine) railway the ties are curved lengthwise; on the right-bank (Rhine) railway the rail seats are inclined on the Hosch-Lichthammer system, and on the Alsace-Lorraine railways (Fig. 37) a hooked tie plate was used. (*See* Part I, Germany.)

LIVESEY (Fig. 39).—This is a development of the Livesey plate tie, being a pressed steel trough tie. At each rail seat are two clamps secured by two rivets each. The outer one bears on the flange of the rail, while the inner one has a steel key driven between it and the rail.

Next to these, in approximate order of date, may be mentioned the Heindl tie (Austria) (Fig. 40), Post tie (Holland), Guillaume tie (Eastern Railway of France), Severac and Bernard ties (Northern Railway of France), and Paullet and Lavalette tie (State Railways of France). All of these have been described and illustrated in the reports.

It would not be fair to close this historical review without reference to the very elaborate and comprehensive historical and descriptive work "Das Eisenbahn Geleise" (Railway Track), written by the well-known German engineer, Mr. A. Haarmann, general director of the Georg-Marien Iron Works at Osnabruck. This book was published in 1891. It is in two volumes, with 852 pages and 1,837 illustrations in the text. Mr. Haarmann is well known as one of the leading German authorities on railway matters, and he has devoted much time to the investigation of the history and development of railway track, the study of which he has made a specialty. He was one of the first engineers to introduce the question of metal track for modern railways, and is the inventor of several forms of metal track which have been used in Germany and elsewhere, as described in this and my former report. The track of modern American railways is treated quite fully, a feature in which Mr. Haarmann's book differs essentially from most other foreign publications on railways. The subjects treated are as follows, each being traced from its earliest history to recent practice in various countries: "Rails;" "Cross-ties and longitudinals of wood, iron, and stone;" "Iron and stone blocks and bowls for ties;" "Fastenings of rails to ties;" "Rail joints;" "Self-supporting rails;" "Switches and frogs;" "Ballast and drainage;" "Maintenance and repairs." In the part referring to metal ties a large amount of the material is quoted from my former report, and numerous varieties of metal track construction are illustrated.

PART III.

WOODEN TIES, PRESERVATIVE PROCESSES, AND METAL TIE PLATES.

GENERAL REMARKS.

In other reports issued by the Forestry Division the subjects of economy in the use of wooden ties, and the necessity for the prompt adoption and carrying into effect of a system of forestry and timber conservation, have been fully dealt with. While the aggregate consumption of timber amounts to a serious figure, a more serious matter is the fact that this consumption represents but a part of the total annual removal of standing timber and reduction of the timber resources by the reckless and wasteful methods of cutting, the wholesale illegal cutting of timber on Government and private lands, and the destruction by forest fires. Consideration of all these matters shows the necessity not only for a wise economy in the use of timber but also the necessity for forest protection. The treatment of timber resources as a source of revenue to the Government, and the consequent placing of these resources under the charge of a skilled body of men as a Government bureau to regulate the cutting, reforestation, etc., have been so markedly successful in other countries, that I am impelled to strongly urge the adoption of a similar system of forest regulation by the Government of the United States.

The desirability of economy has been based upon the consideration that consumption of timber in this country in general is excessive, as compared with reproduction, and that tie material especially is largely derived from young trees, thereby curtailing the needful supplies of the future.

Briefly recapitulating statistics as given in the previous bulletins, it may be stated, that with an average of 2,500 ties per mile the 230,000 miles of track, including second, third, fourth, and side tracks, represent 575,000,000 ties in service. Renewals require annually upwards of 75,000,000 ties, new construction 13,000,000 ties, or the total annual consumption in round numbers of 90,000,000 ties equal to 450,000,000 cubic feet of forest-grown material, to which some 60,000,000 cubic feet for bridges and trestle work must be added, making total consumption for railway purposes exceed 500,000,000 cubic feet. This requires the annual culling of the best timber from probably more than 1,000,000 acres and the annual product of at least 50,000,000 acres in good condition, or more than 10 per cent of the present forest area of the United States reserved for this one use alone.

Wooden ties will undoubtedly continue to be generally used in this country for many years, but great economy in their use can be effected, to the benefit of the railways and of the country in general. The use of preservative processes to prevent decay, and of protective metal tie-plates to prevent the wear and disintegration (and consequent local rot) under the rails, may be made to effect a direct economy by increasing the life of the ties, reducing the expenses of renewals, and enabling cheaper and (if untreated) inferior timbers to be effectively used, besides making a better track which requires less work for maintenance. The adoption of such preservative and protective methods is, therefore, strongly to be advocated. Greater care in inspection for renewals, so as to insure that the ties are allowed to give their full effective life, will also result in economy, as has been amply proved by engineers of maintenance of way. Still another means of economy is the use of some more efficient rail fastening than the ordinary spike, which is insufficient for the heavy rails and heavy traffic of busy main tracks. It is not within the scope of this present report, however, to go into the details of these matters. As an instance of the practical economies to be thus effected, however, I give the following extract from a letter written to me in May, 1892, by Mr. C. P. Huntington, president of the Southern Pacific Railway:

> Our people on the Pacific Coast believe that so long as redwood ties can be obtained at anything like the present prices, they will be, for some time, the cheapest tie for them to use. They are now trying to obviate the only objection to redwood ties, i. e., rapid wear, by the use of tie plates; and if they succeed in this, with moderate cost, the service of the tie can be prolonged for a number of years. As an illustration of the life of this tie, we took up, in 1890, redwood ties laid in 1855, near Folsom, on the Sacramento and Placerville road, which were perfectly sound, but the base of the rail had worn the tie from its original thickness of five inches to three and one-half inches.

In the tie and timber exhibit of the Forestry Division at the World's Columbian Exposition at Chicago, in 1893, there was a redwood tie of "black" redwood (the best quality), which had been in service for twenty-three years (1870 to 1893) near San Jose, Cal., on the Southern Pacific Railway. The ordinary life of these ties is five years and upward, but they rarely fail from decay, being cut out by the rails, which, however, is now prevented by the use of metal tie plates. There was also a tie of red fir, which was in the track, under light traffic, on the Central Pacific Railway, for twenty-five years (1869 to 1893), having been laid on an "alkali flat" and preserved by the salts in the earth. Similar ties in ordinary soil last from six to eight years. It is said that there are numerous spots in New Mexico where the soil is impregnated with alkali, so much so in places that no vegetation can live. In other places nothing but a worthless salt grass thrives. Where the roadbed has been made over these spots it is noticeable that the ties have not decayed, many of the original untreated ties laid in 1879 being still perfectly sound. It is considered not improbable that the substance with which these soils are impregnated might be utilized in some chemical process for the preservation of timber.

WOODEN TIES.

There is no economy in the use of ties of poor quality. The cost of placing is the same, they give worse service, they require more frequent attention, and the maintenance and renewals therefore cost more, while the more frequent disturbance of the ballast and track makes it almost impossible to maintain a good riding track. It is therefore no economy to buy a lot of ties simply because they are cheap. An important economy obtained by the use of good ties and of methods of increasing their life is the lessened disturbance of the track, thus permitting the ties to find a solid bearing in the ballast and remain upon it. In this lies one of the reasons for maintenance economy with good metal ties, which, when once well seated, may be left for many months with very little work on the ballast.

White oak is the best wood, both for wear and durability combined, being very hard and slow to rot, but generally fails rather by decay than by wear. Its average life is about eight years under heavy traffic, though it sometimes lasts twelve years. Burr or rock oak, post oak, and chestnut oak are second in value, but chestnut oak cut in May or June for tan bark must be seasoned differently from that cut in the winter. These oaks last about six to ten years, and are largely used for switch timbers. Pin oak is a medium quality. Black, red, and yellow oak, which are frequently named indiscriminately, are decidedly inferior species, lasting only about four or five years, as a rule, and as they decay from the interior they are somewhat treacherous. Oak ties usually decay first in the part bedded in the ballast.

Pine is very largely used in its numerous varieties, of which yellow and white pine are the best, as, although they, especially the latter, are soft, they are slow to decay, and last from seven to eight years under heavy traffic, or ten years under light traffic. The objections to tapped pine (or timber from which the turpentine has been drawn) on the ground of inferior strength and quality, have been proved to be groundless. There is also little reason for specifications that exclude long-leaf pine grown north of South Carolina, except that as most of such timber in that region has already been cut it is doubtful if it can be obtained in quantity, and the danger of substitution is hence greater, especially as few persons can, in a lot of timber, distinguish one species of Southern pine from the other. Yellow pine is very extensively used, and will decay in about six years, though it will resist wear for ten or even twelve years. It is often preferred to oak for bridge ties, as it does not warp or twist so much.

Chestnut is equal to oak in point of durability. White chestnut may last ten years on tangents or under light traffic, but with heavy traffic it cuts under the rails, and on curves it does not hold the spikes well. The ties have a tendency to split, and they usually decay first in the part above the ballast.

The various cedars are good and durable timbers, red and white cedar being used. They last for ten or more years, but with heavy traffic their softness leads to cutting under the rails, and, like chestnut, the wood does not hold the spikes well on curves.

Tamarack, or hackmatack (larch), is very commonly used, and will last from five to ten years, or more.

Black cypress is much used in the South, where there is an abundant supply. It is soft, but durable, lasting perhaps ten years if protected by metal tie plates.

Hemlock is as a rule neither hard nor durable, and its life is very variable. It is extensively used on account of its cheapness, but is not used for first-class track. It gets soft under the rails and at the spike holes. Spruce is about the same, lasting three to seven years.

Redwood is extremely durable, but being soft it cuts badly under the rails. Its ordinary life on the Southern Pacific Railway is from five years upward, depending upon the traffic, but some specimens of "black redwood" (the best quality) last over twenty years. The ties usually fail by cutting out under the rail, which may be prevented by the use of metal tie plates.

Red beech and red elm are fairly hard and durable. Black locust, which is a quick-growing timber, and hickory are good, but scarce, and have a life of about seven to ten years. Maple, ash, birch, cherry, butternut, and white beech are of little value, and maple especially rots rapidly, while cherry tends to split in spiking. Mulberry and black walnut are used to a limited extent, and mesquite and catalpa are also used in the Southwest.

According to the statistics presented in Bulletin IV, the distribution is about as follows, in percentage of the total number of ties in service:

	Per cent.
Oak	60
Pine	20
Cedar	6
Chestnut	5
Hemlock and tamarack	3
Redwood	3
Cypress	2
Various	1

The following table shows the life of ties on a number of railways, but it must be borne in mind that the life varies considerably in different sections of the country and on different roads, owing to the varying qualities of the same species of timber and to the varying conditions of climate, weather, roadbed, and traffic. Roads which obtain ties continually from one section of the country often find that the life of the ties is gradually becoming less as the timber resources become picked over.

Ties usually fail by "spike-killing" and cutting on curves, and have to be taken out for their inability to hold the rails to gauge, although they would be good for two or three years more on tangents. The ties usually last longer in good, well-drained ballast, depending somewhat upon the form of cross section, but in some sandy soils they decay even quicker than in clay soil, the former supplying the warmth, air, and moisture necessary for fermentation, while the latter excludes air and warmth. The Minneapolis, St. Paul and Sault Sainte Marie Railway finds that ties in sand ballast, level with top of tie and extending 12 inches beyond the ends, give fully one year less service than in gravel ballast sloped from 1 inch above the tie at the middle to 3 inches below the top at the ends, and last best on the prairie lines with loam ballast 2 inches above the tie at the middle and sloped to the bottom at the ends. The traffic is lighter on the prairie lines. On the Missouri, Kansas and Texas Railway ties of white oak, post oak, burr oak, cherry, and sassafras have an average life of six to seven years in natural soil, and eight years in broken-stone or gravel under the usual traffic of Western roads. The Allegheny Valley Railway finds that good white oak ties in well-drained broken-stone ballast average about nine years under a traffic ot 4,500,000 tons per annum. The Central Railway of New Jersey finds that first-class oak and yellow pine ties on main tracks last about eight years in stone or engine cinders, and a little less in gravel. On the Union Pacific Railway system the average life in different localities and under different conditions is as follows:

Colorado Division.—Natural ballast and moderate traffic: Oak, ten years; red spruce, eight years; pine, five years.

Idaho Division.—Gravel or sandy ballast: Native yellow pine ties, six to eight years under heavy traffic, and twelve years under light traffic.

Kansas Division.—White oak, six years with heavy and somewhat more with light traffic.

Pacific Division.—Gravel ballast and ordinary traffic: Fir, six years; tamarack, five years; mountain pine, four years.

Wyoming Division.—White oak, ten years; white cedar, eight or nine years; burnettized pine, seven to nine years; pine, six years in clay or gravel ballast, and five years in sandy soil; Oregon fir and pine, four years in gravel, sand, and loam, six years in alkali earth.

Life of railway ties.

Railway.	Ties.	Average life in years.
Delaware and Hudson	White oak	7 to 12
Do	Chestnut	5 to 10
Lake Shore and Michigan Southern.	White oak	6
Lehigh Valley	White and rock oak.	8
Do	Cypress	8
Do	Chestnut	8
Do	Yellow pine	7
Pennsylvania	White oak	5 to 6
Do	Rock oak	5 to 6
Allegheny Valley	White oak	9
Central of New Jersey	Oak	3
Do	Yellow pine	8
Do	Chestnut	6
Baltimore and Ohio	Oak	8
Boston and Maine	Chestnut, cedar and hemlock.	5 to 7
Michigan Central	Oak	6 to 9
Do	Cedar	6 to 9
Do	Tamarack	4
Do	Hemlock	4
Cleveland, Cincinnati, Chicago and St. Louis.	White, burr and chestnut oak; wild cherry, honey locust, and black walnut.	About 9
Alabama Midland	Yellow pine	5 to 6
Nashville, Chattanooga and St. Louis.	White or post oak.	6
Missouri, Kansas and, Texas.	White, post, and burr oak; cherry and sassafras.	6 to 8
Burlington, Cedar Rapids and Northern.	White oak and cedar.	8¼
Flint and Pere Marquette.	Hemlock	5
Do	White oak	8 to 9
Do	Cedar	8 to 10
Chicago and Alton	Oak	8
Do	Cedar	6
Chicago and Northwestern.	White oak	6 to 8
Do	Cedar	10 to 12
Do	Hemlock	5 to 7
Minneapolis, Saint Paul and Sault Ste. Marie.	Cedar and oak	8 to 10
Do	Hemlock and tamarack.	6 to 7
Denver and Rio Grande.	Red spruce	6
Do	Yellow pine	5
Union Pacific	Oak	6 to 10
Do	Pine	5 to 8
Do	Red spruce	8
Do	White cedar	8 to 9
Do	Pine (burnetized).	7 to 9
Do	Oregon fir and pine.	4 to 7
Do	Tamarack	5
Louisville and Nashville.	White and post oak.	7 to 8
Chicago, Burlington and Quincy.	Oak, cedar	8
Do	Yellow pine	5 to 7

The following information on the use of wood in railroad ties is in part taken (condensed and rearranged) from former publications of the Forestry Division.

Young wood is more apt to decay than the wood of older timber, owing to its larger proportion of albuminates, which form the food of the fungi. On the other hand, the idea that old coarse timber is more liable to decay than the young timber is not of general application. The young timber is sometimes assumed to be more tough and fibrous and therefore better fitted to resist decay, but as the sapwood of such ties becomes rotten in a few years, the size is reduced so that they are renewed without regard to the soundness of the heart. Sound, mature, well-grown trees yield more durable timber than either very young or very old trees. Timber of rapid growth (indicated by broad annual rings), due to favorable conditions of soil and light, yields the most durable timber in hard woods, and second growth should, in general, be equal to first growth. In coniferous wood, however, slow growth (indicated by narrow rings) yields the better timber. The most durable material for ties, therefore, is furnished by coniferous woods from comparatively poor soils, high altitudes, and dense forest; and by hard woods from rich, deep, warm soils and isolated positions. In all cases within the same species the heavier and denser wood is the most durable, and the heart wood is, of course, more durable than the sapwood.

Winter is the best time for felling tie timber, especially if it is to be used without being seasoned, as it then contains less fermentable sap and seasons more slowly and evenly before the temperature is warm enough to cause fermentation to set in. With timber cut while in leaf (as in the case of chestnut oak cut for tanbark), the trees should be left for a few weeks before cutting to size. While in general ties are cut in the fall and winter, which is no doubt the best practice, in the South cutting of pine during the summer is often practiced without any apparently good reason. Timber cut when the sap is at rest is more durable (mainly because fungous growth is less active) than that cut when the sap is moving.

Ties should always be left to season for at least six months, and a year is even better, as ties properly seasoned are far superior in efficiency to those used at once. The ties should be barked and piled rows of eight to twelve, the ties placed about 6 inches apart and the inrows separated by two ties at right angles to them. The pile should rest upon two poles or rough timbers, or upon blocking, as if laid directly on the ground fungous growths will soon attack the lower rows. The ties of the top row should be placed close together and inclined so as to shed the rain. The piles should contain fifty to one hundred ties each and be at least five feet apart to allow of inspection. If piled near the track they should be, wherever possible, on ground atleast as as high as the rails, but the seasoning will be slower and more effective if the ties are piled in the woods. Large timbers, as for switch ties, bridge stringers, etc., should be seasoned under cover, as otherwise the sun may cause them to season irregularly. More rapid seasoning may be effected by sinking the ties in running water for two weeks or more. On the Atchison, Topeka and Santa Fe Railway it is found that pine ties cut in summer and placed in the track while green last three years; if cut in winter and seasoned they last five years, or five and one-half years if seasoned in water. The following is an extract from the report on "Inspection and distribution of track ties," presented at the annual meeting of the Roadmaster's Association of America, in September, 1894:

> The work of inspection and distribution of track ties is necessarily governed by the conditions and circumstances of each individual case. Where the ties are furnished along the line of the railway they should be delivered at a loading track, piled up in square piles, not nearer than 6 and not more than 20 feet from the rail. They should be piled with spaces between to admit of inspection, as well as circulation around them. They should all be delivered before March 1, so that they can be inspected, and the distribution begun before the spring work opens up. When they are received beyond the line of the purchasing road the inspector should be present when they are loaded into cars, and a check of the number of each grade kept by car load and reported to the track department, giving car number and initials. They should be counted when unloaded to check the inspector's tally.
>
> The inspector should be a man of honesty, tact, and great moral courage, and his inspection should be fully sustained by the purchaser. When ties are purchased in large quantities the temptation to include poor ones is very great. Large sums of money are involved and great pressure is often brought to bear on the inspector to

move him from insisting rigidly on the specifications. Several cases have come to the knowledge of your committee in which the inspector was removed through unfair means, evil reports, deceptions, etc., for endeavoring to follow strictly the specifications under which the ties were purchased.

We can not omit to refer to the importance of having the ties cut in the fall and early winter for the following season's supply. Experiments show that timber cut between January 1 and August 1 is very much less durable than timber cut between August and January, and its value decreases rapidly as the sap season is approached.

The report as printed was worded as above, but on discussion, before the report was accepted, it was changed to read that "timber cut when the sap is up is less durable than that cut when the sap is down." These ideas of the sap, however, are somewhat antiquated according to our modern knowledge, and the original wording, as given above, was really better than the innovation. The discussion on this report showed a great diversity of ideas on the question of ties.

Hewed ties are very generally assumed to be superior to sawed ties, and this has led to a custom of insisting upon ties cut from trees that will make but one tie, or to insist that the cut shall make but one tie. There are two reasons why a sawed tie is apt to decay more rapidly than a hewed tie: (1) The saw does not make a sharp cut but leaves a more or less woolly surface, which permits the accumulation of water and affords opportunity for fungous growth;[1] (2) the sawing increases the end surfaces of the grain, as the cut can not be kept parallel with the fiber, especially when the log is not quite straight, thus exposing bastard faces on the sides which are simply partial cross sections. Different roads, however, have different opinions and experience in this direction. Mr. W. W. Rich, chief engineer of the Minneapolis, St. Paul and Sault Ste. Marie Railway, states that he prefers ties made from round timber, sawed on two sides instead of hewed, as experience indicates that the former give longer service than the latter, though this result was not expected and is contrary to tradition. The Cleveland, Cincinnati, Chicago, and St. Louis Railway requires sawed ties to be 9 inches wide, instead of 8 inches as specified for hewed ties. Sawed ties are being more and more used, and if treated by preservative processes the two objections above noted are eliminated. The objections to split ties are also passing away, except that of the quicker and deeper season checking which takes place in a split tie with the heart on one side. Warped and twisted ties should not be used as they are liable to rock in the ballast.

Ties should invariably be stripped of the bark. They should be of uniform size and those of the same kind should as far as possible be kept together, in order to insure approximate uniformity in wear. The thickness varies from 6 to 8 inches, but should never be less than 6 inches, the deeper ties having greater stiffness to resist transverse bending. The width is from 6 to 10 (or even 12) inches, but 8 inches gives a good seat for the rail and a good bed in the ballast, while very wide ties are liable to rock. The ordinary lengths are 8 feet and 8 feet 6 inches. Uniformity of size should be required by the specifications, and conformity with the requirements insisted upon by the inspector, as ties of varying width give an irregular bearing to the rail, and ties of varying thickness involve too much disturbance of the ballast in renewals. The standard size of ties of a few roads are given below:

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[1] This objection may be avoided by the use of a planer-saw, which cuts and planes at the same time.—B. E. F.

Railway.	Size of tie.			Railway.	Size of tie.		
	Length.	Thickness.	Width.		Length.	Thickness.	Width.
	Feet.	*Inches.*	*Inches.*		*Feet.*	*Inches.*	*Inches.*
Chicago and North Western	8	6	8	New York Central	8	7	8
Nashville, Chattanooga and St. Louis	8½	7	8	Allegheny Valley	8½	7	9
Central of New Jersey	8½	6	6	Pittsburg and Lake Erie	8½	7	9
Do	8½	7	9	Louisville and Nashville.‡	8½	7	9
Union Pacific*	8	6	8	Missouri, Kansas and Texas	8	6	8
Do.†	8	7	8	Cleveland, Cincinnati, Chicago and St. Louis	8	7	8
Illinois Central	8	6	8				

* Oak and cedar. † Pine, fir, and spruce. ‡ Sometimes 9 feet.

There are two principal qualities governing the life of a tie: (1) Its resistance to natural decay; (2) its resistance to the wear resulting from the cutting and abrading action of the rail (the direct compression of the wood is too slight to enter into consideration). Ties in service are injured, destroyed, or rendered unserviceable by three principal causes: (1) Mechanical disintegration and abrasion of the fibers under the rails; (2) injury by splitting and respiking; (3) general or natural decay of the wood, induced by fungi. Under average and ordinary conditions on American railways the ties have to be renewed more on account of the cutting and abrasion (and consequent local rot) under the rails than on account of natural decay; but the former causes of renewal may be largely reduced by the use of better rail fastenings (to hold the rail more securely than the ordinary spike) and the use of metal tie-plates to protect the wood. Ties will wear out quicker on curves on account of the strain on the rail forcing the spikes back, enlarging the spike holes and reducing the hold of the spikes in the tie. They will also wear out more quickly on heavy grades, where sand is used by the engines. In both of these cases it is assumed that tie-plates are not used. Ties usually begin to decay first at the ends and second at the rail seats. The first is a normal trouble, much hastened by season checking, and may be overcome by painting the ends with rosin or some cheap paint, so as to cause a slower exchange of moisture.

Ties should be made from sound, thrifty, live, or green timber, free from loose or rotten knots, wormholes, dry rot, windshakes, splits, or other imperfections which affect their strength or durability. They should have no sap wood on either face and not more than 1 inch on the edges or corners. They should be hewed or sawed with the faces perfectly true and parallel, of the exact dimensions specified; the faces out of wind, smooth, and free from any inequality of surface, deep or bad score marks, or splinters; and they should be not more than 3 inches out of straight in any direction.

RENEWALS OF WOODEN TIES.

The tie renewals are too frequently considered as a comparatively unimportant item in the expense account of maintenance of way, but in point of fact the average cost of tie renewals on many roads already exceeds that of rail renewals, and shows a tendency to increase in a marked degree, for the following reasons: (1) Gradual increase in price, owing to the increased value of timber as the supply becomes exhausted, and to the increased haul as sources of supply become distant. (2) The marketing of the best timber, so that the poorer qualities must be cut for ties, giving consequently inferior service, especially if ties from young and undersized trees are accepted. (3) Less rigid inspection, and the acceptance of inferior ties. (4) Greater tendency to local rot and cutting under the rails, due to increased wheel loads and growing traffic. (5) Spike-killing, caused by regauging, redriving loosened spikes, etc. The renewals average about 250 to 350 ties per mile per year for main tracks, and 200 to 250 for side tracks, but these figures are reduced very considerably where treated ties and metal tie-plates are used. A road which has to renew its ties in five years is at a great disadvantage as compared with one whose ties last ten years, as the former must figure into its expense almost double the cost for material, besides the additional track labor necessary to do the work, while during the interval it can not have as good a track as the latter.

In a paper on "The increasing cost of railway tie renewals" (Transactions American Society of Civil Engineers, December, 1892), Mr. Benjamin Reece pointed out that while a few years ago the cost of such renewals was but a fraction of the cost of rail renewals, now the figures are reversed, and the tie renewals offer an opportunity for large reductions in expenses. Close attention, he says, has been paid to the purchase of rails, to their design, their life and wear, etc., while the ties have too often been comparatively neglected. The fact of the increase in cost of tie renewals is often only vaguely recognized, and its magnitude not realized. He gave statistics from a number of lines, showing an increasing ratio of tie renewals to rail renewals, reaching in 1890-'91 to 100 for rails and 111 to 398 for ties. "In the light of such facts is it not strange that on many lines where a requisition for a few kegs of spikes is passed through several hands for scrutiny and approval, orders for several hundred thousand ties are accepted and approved on sight."

A marked saving may be effected by introducing systematized checks for preventing the premature removal of comparatively sound ties from the track, a practice which many section foremen have, and attention to this point has on some roads been attended with a gratifying reduction in tie renewals. If the officers of a road grant requisitions for ties liberally and without question, there will be a tendency to take out ties before they have given their proper service; while, on the other hand, if the officers are parsimonious and habitually cut down requisitions for ties, there will be many ties left too long in the track.

Well-devised plans should be instituted for preparing careful estimates of each season's requirements, and the practice varies greatly, some roads being very careful and others very careless. On the Louisville and Nashville Railway the custom is to prepare estimates before July showing the number of ties required on each division, the estimates being made from actual count of ties in the track that should properly come out during the next twelve months. The count is made by the section foremen, checked and certified by the respective supervisors and roadmasters, approved by the superintendents after investigation, and forwarded by them to the chief engineer, who is supposed to have a general knowledge of the condition of ties on the entire line, and if the requisitions differ widely from what he expected, they are returned for further investigation and revision if necessary. Finally, the requisitions are forwarded to the general manager, with a request for authority to contract for the ties needed, and with them is sent a statement showing the average number of ties per mile used on each division during the ten years previous, and where the number called for appears excessive as compared with the average, explanation is made. On the Nashville, Chattanooga and St. Louis Railway the ties are inspected and counted for renewal by the section foremen, under the supervision of the roadmaster. On this road the tie renewals are under the transportation department and not under the chief engineer, which is not good practice. On the Chicago and Northwestern Railway each section foreman marks with an ax the ties which he thinks should be removed, after which the roadmasters go over their divisions to see whether the foremen's judgment is correct, and they generally cut down the number very considerably.

The section foreman should determine by actual count, and not by a guess estimate, the number of ties which he considers he will need on each mile of his section, marking the ties, and reporting the number to the roadmaster. The latter should personally verify the estimate, for while ties are often left in too long, yet many foremen condemn ties which are good. Ties should never be renewed without permission, and those taken out should not be burned or removed from the right of way until inspected by some officer thoroughly and practically familiar with the use of ties and the amount of work that can safely be got out of them. On some roads the foremen are forbidden to remove ties having more than 4 inches of good timber left under the rail. Records should be kept of the annual renewals, and if a very high requisition is made in any one year investigation should be made.

It is an excellent plan to mark the ties in some way so that their length of service can be seen at once, and a record kept of them. Then, if ties are found to be taken out after only a few years' service, the reason should be investigated. Of course this marking should not be made a basis for renewals, the ties being still, as ordinarily, taken out only when examination shows the necessity of so doing, irrespective of the marks, as the great differences in the enduring qualities of ties, apparently from the same lot and place, make it quite possible that one tie may become unfit for further service in four or five years, while its neighbors from the same lot may be good for eight years' service.

On the Allegheny Valley Railway the system of marking is by cutting a small V notch with an axe or adze in the edge of the tie at the time of placing it in the track, the position of the notch indicating the year. The ties are hauled in from the woods in the winter months and are, as a rule, placed in the track early in the year, so that a glance at the marking while passing along the track will show the observer both the age of the tie from the tree and its length of service. The track foremen make simple reports of the ties taken out and their age as indicated by the marks, which reports are tabulated and filed, forming a record of the average life of the ties. The number of ties estimated for renewals is advertised for by the purchasing agent, who inspects them for acceptance or rejection. On the Cleveland division of the Cleveland, Cincinnati, Chicago and St. Louis Railway it has been the practice to mark the ties when they are put in the track, and this enables the officers to secure definite information in regard to the length of service and life in the different kinds of ballast (broken stone, furnace slag, gravel, and cinders). For this purpose a stamp is used with letters about 1½ inches long giving the year. The stamp weighs about 3½ pounds, and the marking is done by a blow with a hammer, the mark being made on the top and the south end of the tie. In Germany it has been found that the impressions made by such hammer-stamps on preserved ties became effaced before the time for renewal, and nails or tacks with distinguishing letters or marks were therefore substituted. The Atchison, Topeka and Santa Fe Railway stamps the date of treatment on its burnetized ties.

The following table shows the ratio of tie renewals to rail renewals for several railways during periods of a few years, the rail renewals being taken as 100 in each case. The figures given are the result of the cost of tie renewals divided by the cost of rail renewals and multiplied by 100. The Lake Shore and Michigan Southern Railway and the Michigan Central Railway are the only ones on which there seems to be a sign of decrease in the relative cost of tie and rail renewals.

Railway.	1878-'81.	1882-'85.	1884-'86.	1886-'89.	1887-'89.	1890-'91.
Union Pacific	37	115		165		296
Union Pacific system			140		201	279
Atchison, Topeka and Santa Fe			67		174	255
Northern Pacific	144	158		730		398
Chicago, Milwaukee and Saint Paul			80		141	200
Chicago and Northwestern	61	101		143		224
Lake Shore and Michigan Southern	80	172		138		111
Michigan Central	42	133		148		125
Louisville and Nashville		47		102		216
Richmond and Danville	40	52		117		242
Philadelphia and Reading		73		98		289

WOODEN TIES IN FOREIGN COUNTRIES.

In the detailed statements in Part I of this report much information will be found in regard to the wooden ties used in various countries, and some general notes in regard to the same are given below. In France the importation of the quebracho colorado from South America has been advocated, and in this country it has been proposed to import some of the extremely hard woods from Australia. Such importation, however, does not appear likely to be at all extensive, owing to the cost, especially as economy with our own ties may be effected to a very considerable extent by the use of preservative processes and protective plates, while with a proper system of forestry we have an abundant supply of good timber for such economized use, until such time as the metal tie becomes a more practical factor in railway track work.

The use by French railways of quebracho wood (*Quebracho colorado*) from the Argentine Republic was advocated in 1893 by Mr. Poulet, an engineer on the Argentine Sante Fe Railway. This wood contains a large proportion of its weight of tannin, from 15 to 20 per cent, for which reason it is much used by tanneries, and this, together with its hardness and weight, makes it a very suitable material for ties. In South America it is used for ties, bridges, etc., and posts that have been in use for nearly one hundred years in cattle corrals, etc., have been found in good condition, the part in the ground being as good as that exposed. Its weight averages 78 pounds per cubic meter, so that a tie 8.2 feet long and 10 by 6 inches section (2.5 by 0.25 by 0.15 meters) weighs about 257 pounds. It is so hard that it does not wear under the rails, and spike holes must be bored. Other timbers used for ties in South and Central America include oak, mesquite, lignum-vitae, vera (a species of greenheart), mahogany, catalpa, and imported creosoted pine.

In Australia there are the ironbark, jarrah, blue and red gum, karri, etc., which are very hard and dense, and of great weight, 60 to 65 pounds per cubic foot. They are so hard that they do not cut under T rails, and tie-plates are therefore not required. The ironbark and jarrah (of the eucalyptus family) are specially noted for their durability, being generally considered as indestructible by fungi, or by the teredo or other boring worms. They also hold spikes well and resist abrasion. The cost in Australia is about 60 cents per cubic foot, or $1.80 for a tie 6 by 9 inches and 8 feet long. It is thought that they could be imported and sold here at that price, ironbark ties costing $1.80 and lasting twenty-five years being superior to yellow pine ties costing 55 cents and lasting nine years (if protected by tie plates). On the other hand, Mr. J. W. James, in a paper on "Timber in the Tropics, the Teredo Navalis, and the White Ant" (Proceedings, Institution of Civil Engineers, 1890–'91), stated that while at Port Darwin, South Australia, he found jarrah piles of a jetty so seriously attacked by the teredo that it was decided to sheath all the timber with muntz metal up to high-water line. The karri wood used temporarily for chafing timbers was also attacked, and Mr. James found living specimens of the teredo (?) in some of these timbers which had been removed and had laid for two months on the deck of the jetty, exposed to the tropical sun. He also found railway ties of well-seasoned jarrah and sugar gum eaten away about ¼-inch by white ants, and though preservative compounds called "carbolineum avenarius" and "anti-termite" were used, they seemed merely to check the destruction of the wood for a time. Ironbark from New South Wales and karri and jarrah from Western Australia, which are not attacked in the southern part of the continent, are attacked in the northern part, the ants being more troublesome in the hotter territory. At the World's Columbian Exposition, held at Chicago in 1893, the New South Wales government railways exhibited specimens of track laid with T rails and with double-head rails in cast-iron chairs. The former rest directly on ironbark ties 9 feet long, 10 by 5 inches section, spaced about 30 inches center to center, the rails being secured on the outside by lag screws with heads 1⅝ inches square, and on the inside by spikes with heads 1½ inches square, the heads being much heavier than those of American spikes. The chairs for double-headed rails have a base 14½ by 7½ inches, with holes for four round spikes, but only two spikes are used at once, except on the joint ties, where each chair has three spikes. The spike holes are bored when the ties are in the track. The ties exhibited had been in service for twenty-three or twenty-four years, under continuous traffic, and were in excellent condition.

In India some Australian karri ties laid on the ghat or mountain lines of the Southern Mahratta Railway in 1886, were so deteriorated by the excessive moisture that they had to be replaced in 1893–'94. The ironbark ties used in Australia cost about $1.08 each, and last about twenty years. They would cost about 4½ cents per annum for renewals and save the labor of three to six relayings, as compared with an average of American oak ties, costing 78 cents each and lasting seven years, with an average of 12 cents per year for renewals, as an average of all American tie timbers. Ironbark and jarrah are not the same, but both are species of the large genus (nearly 300 species) of eucalyptus, namely, eucalyptus leucoxylon, the ironbark; and eucalyptus marginata, the jarrah or mahogany tree. Mr. Fernow considers that, with the quality claimed for these timbers, they might well compete with the best oak of the United States for railway purposes in the eastern markets.

The South Australian government railways use hard-wood ties, the hardness rendering the use of metal tie plates unnecessary under the T rails. The ties are 8 feet 6 inches long (for a gauge of 5 feet 3 inches), 10 inches wide, and 5 inches thick. They are of blue gum, weighing 65 pounds per cubic foot; red gum, 63 pounds; sugar gum, 63 pounds; jarrah, 63 pounds, and karri, 61 pounds. The rails are fastened on the outside by clamps and fang bolts, and on the inside by ⅝-inch square spikes. The joint ties are spaced 2 feet 7½ inches and the intermediate ties 2 feet 5¾ inches, center to center. The timber supply in this colony is limited, and in several cases structures have been designed to be built of old rails, so as to use up a quantity of old iron which could not be reworked as scrap. In 1891 ties bought by contract or from the conservator of forests cost from $1.12 to $1.40 each. The engineer in chief of the South Australian government railways considers that in the northern territory the white ants would destroy even the hard-wood timbers.

On the government railways of New Zealand various native and imported timbers were used up to 1885, but the supply of the best timbers began to diminish and the price increased with the demand for ties for construction and maintenance. As the forests contained many timbers suitable for ties, except for their liability to decay, the government decided to try the creosoting process, as noted further on. Similar investigations and experiments have been made in Cape Colony and Natal (South Africa). On the Tongkin and Tientsin Railway, China, the ties are of hinoki and chestnut from Japan. The latter are 9 by 5 inches section, and 8 feet long, while the former are 1 inch thicker, the wood being soft. The price delivered was 54 to 66 cents per tie.

Two English railways intend to try the Australian hardwood timber, the London, Brighton and South Coast Railway having ordered 1,000 iron-bark ties, and the Great Eastern Railway 2,000 red-gum ties. These ties are ordered through the Agricultural Department of New South Wales. It is estimated that they should last at least eighteen years, but the question of relative cost will have to be considered.

In France the annual consumption of ties for maintenance was reduced steadily from 170 ties per mile of single track in 1883 to 84 ties per mile in 1889. This was due to increased care, improved methods of renewal, creosoting ties of all kinds, better fastenings, better ballast, and heavier rails. The number of ties consumed in 1889 was 3,241,356, of which 369,000 were for construction. Most of these were of oak, next beech and fir, and only a small percentage were imported. Since

1889 the renewals have been about 85 per mile, or 4.4 per cent per annum. The ties used on the 27,681 miles of the seven great railway systems in 1889 included 2,155,921 of oak, 696,602 of beech, and 388,833 of red spruce.

PRESERVATIVE PROCESSES FOR WOODEN TIES.

In Appendix No. 3 of this report is given a valuable and interesting paper on the subject of timber preservation, by Mr. Henry Flad, C. E., and also a paper on wood creosote oil by Capt. W. H. Bixby, U. S. Engineer Corps, both of which papers are reprinted from Bulletin No. 1 of the Forestry Division, issued in 1887. As the general principles of the several processes, and the particulars of the use of the processes, are dealt with in Mr. Flad's paper, it is only intended in this part of the report to give the details of some processes as developed within recent years, and more especially to give specific details of the methods of practice now followed at works in this country.

The subject of the use of preservative processes for wooden ties as a means of securing a better track with reduced maintenance expenses, has not been given the careful attention in this country which its importance demands, and though the resultant practical economies have been amply proved in other countries, they have been but indifferently recognized here by railway officers, with some important exceptions. The economy results not only from the increased life of the ties, and the possibilities of making inferior and cheaper timber give as good service as more expensive timbers, but also from the reduced labor and cost of maintenance, and the improved surface of track due to reduction in renewals; for, under ordinary conditions, the track has hardly been got into good surface on a settled bed, than it is disturbed by tie renewals. In most of the processes the principle of the treatment is to extract the sap and replace it by a material which will fill the cells of the wood and prevent fermentation and decay. The vulcanizing process, however, is claimed to effect a chemical change in the constituents of the sap itself, being practically a seasoning process. The impregnating processes are more successful with timber of open grain, such as pine, than with the denser timbers, such as oak. The timber, in most processes (see Boucherie process, p. 244), should be thoroughly seasoned before treatment, and it is waste of time and money to hurriedly treat measured timber required for immediate use, though this is sometimes done owing to the contracts for ties not being placed in proper time. Whatever process is used, it is absolutely essential that it should be carried out carefully and thoroughly, if the best results are to be obtained. For this reason, among others, several large railway companies prefer to operate their own works, which is a good plan, and likely to give satisfactory and economical results if the work is carried on systematically. The various processes used, and their efficiency and economy, etc., have been very fully given in the valuable and exhaustive report of a committee of the

American Society of Civil Engineers (1885), and in Bulletin 1 of the Forestry Division, which is reprinted in the present publication.

In the experiments recently made by Dr. Boehme, to ascertain the relative effect on impregnated and natural wood, samples of various treatment demonstrated that impregnated wood absorbed much less water than the natural wood. Increase in volume in consequence of absorption of water was less in the impregnated than in the natural samples. Tests of the bending strength of the samples showed that those impregnated were stronger by 15 per cent. Resistance to compression was greater by about 22 per cent in the case of the impregnated samples.

It would appear of interest to state here that by creosoting the strength of the timber is also increased. The following results confirming this view are taken from some experiments which were submitted to the British Civil and Mechanical Engineers' Society some time ago. The sizes of the pieces tested were 2 feet 6 inches by 2 inches by 1½ inches; the pressure was applied midway between supports 2 feet apart:

Series No. 1.—Six pieces of Memel fir, not creosoted, weighing 9¼ pounds.		Series No. 2.—Six pieces of Memol fir, creosoted, cut out of the same plank as preceding. weighing 13½ pounds.		Series No. 3.—Six pieces of Scotch fir, not creosoted, weighing 9 pounds.		Series No. 4.—Six pieces of Scotch fir, creosoted, cut out of the same sleeper as the preceding, weighing 16½ pounds.	
	Cwt.		*Cwt.*		*Cwt.*		*Cwt.*
No. 1 broke with	12½	No. 1 broke with	12	No. 1 broke with	15	No. 1 broke with	16
2	10½	2	12	2	14	2	14
3	10½	3	11	3	12½	3	14½
4	11½	4	11	4	13	4	17½
5	11	5	11½	5	13½	5	14
6	10	6	12½	6	14	6	16
Average	11	Average	11⅔	Average	13⅔	Average	15⅓

Summary of Average Results.

	Cwt.
Memel fir not creosoted	11
Memel fir creosoted	11⅔
Scotch fir not creosoted	13⅔
Scotch fir creosoted	15⅔

—(B. E. Fernow, Bulletin No. 1, 1887.)

NOTE.—These statements are given for what they are worth. Later work in the Forestry Division would make it appear highly questionable whether the figures quoted above can be used to prove the case one way or the other. The question must be still considered entirely open.—B. E. F.

The following very interesting statement as to the practice and experience on the Southern Pacific Railway was kindly furnished in April, 1894, for the purpose of this report, by Mr. J. Kruttschnitt, general manager, and the details of the two processes mentioned are given under their respective heads further on:

This company has been placing in its track since 1887 burnettized ties, treated at first at the preserving works of the Houston and Texas Central Railway, at Houston, Tex., and later on, from March, 1891, at its own plant, located on the main line, 2½ miles east of Houston; from which time it has been doing constant service, except for the few months of last summer, when the financial stringency made it advisable for all railways to cut down such expenses as could be deferred until a more propitious time. Work was resumed last December.

The present plant consists of two cylinders, 6 feet diameter and 110 feet long, open at both ends, with narrow gauge tracks running through them. There is an extensive yard at each end of the cylinders, one containing untreated material and the other material that has gone through the preserving process. Each yard is supplied with steam-traveling derricks. In addition, there are the engine house, with steam, vacuum, oil, and water pumps, and the boiler house with boiler and superheater. There are also other structures, such as storage tanks, working tanks, receiving tanks, storehouse and water tank. The kinds of woods treated are long and short leaf yellow pine from eastern Texas and western Louisiana. Chloride of zinc is used for preserving track ties only, and creosote oil for bridge ties and timbers, piles, etc.

To illustrate the effect of the use of treated ties upon the renewals of all kinds of ties, I would state that for the year 1891 these renewals amounted to 243 ties per mile of track, including sidings. For the two succeeding years they were 240 and 205 ties, respectively, per mile of track; and for 1894 our requisitions, even when given a large margin, call for about only 145 ties per mile of track.

The kinds of ballast used are dirt, gravel, and rock. On some parts of the line, especially in the arid regions of western Texas, dirt is the only ballast available and permissible. The other parts of the line are ballasted principally with gravel. The traffic of the road, as regards volume of business, may be considered moderately heavy; the average number of trains passing any one station both ways per day being about 35. The average weight of our passenger engine equipment is 75.52 tons, and that of freight 72.63 tons. The weight of the heaviest freight engines in use on the road is 104.5 tons.

Metal tie plates have been used for the past three years and we have now adopted them altogether on our standard creosoted bridge floors and trestles, and on pieces of track of heavy curvature. At the present time 61,060 tie plates have been placed in use by our bridge and building department and 38,960 by the track department. We require ties to be sawn exactly to the dimensions specified and to be "square edge." We would not accept sap ties for treatment if more than 1 inch of sap face shows on two corners. For yellow-pine ties in general we require them to be square edge and either long or short leaf without reference to sap or heart.

A portable plant for treating timber by impregnation has been patented by William G. Curtis and John D. Isaacs, of San Francisco, Cal. (No. 516730; date, March 20, 1894.) The pumps and tanks are mounted upon flat cars, and the cylinder or retort is mounted upon car trucks, the cylinder being made in sections connected by bolts and flanges and disconnected for convenience of transportation.

A dry-kiln system for rapidly seasoning and preserving timber has been patented by James R. Bate, of Cincinnati, Ohio. (No. 522284; date, July 3, 1894.) The timber is run into the kiln on a car and steam is then admitted, while at the same time a solution of soda ash is injected, this alkali neutralizing the acetic acid of the wood. Steam is then shut off and steam impregnated with oil admitted from a boiler containing oil and water, the oil being claimed to enter the timber. After this second steaming has ceased communication is opened with a furnace in which is burned a compound consisting of 8 per cent carbon, 4 per cent chloride of sodium, and 80 per cent sulphur, the fumes and gases bleaching and toughening (?) the wood.

CREOSOTING.

This is one of the best and most successful processes and is very extensively used abroad, but in this country its introduction has been hindered by the high cost of creosote oil and the consequent expense of the treated ties. The process consists essentially of placing the ties in a large iron cylinder, exhausting the air, heating the ties by steam to soften the cell walls, dissolving the contents of the cells, and then forcing in hot creosote under pressure. The creosote is heated in order to make it sufficiently fluid to enter the wood. Two kinds of oil are used: (1) Dead oil of coal tar, obtained from coal and containing naphthaline as its principal preservative; and (2) wood creosote oil, obtained from the destructive distillation of pine timber, and containing paraffin. The denseness of the dead oil is largely due to the naphthaline, which melts only at 175° F., and if this is liquefied and enters the wood cells it becomes solidified and permanently fixed. Acridine is an important constituent in cresote, and (like naphthaline) remains permanently; while the tar acids, which were formerly supposed to induce coagulation of the albumen in the tie, and thereby to be the principal cause of preservation, are found to disappear in a comparatively short time. Wood creosote oil is much cheaper than the dead oil, and is less dense, while it is so much cheaper that if equally efficient it would very much advance the use of preserved ties. The practical tests, however, have not been of sufficient extent to be conclusive on this point. (*See* Appendix 1.) One of the creosoting companies which used this material, but abandoned it, states that its life as an antiseptic is limited on account of its being more soluble than dead oil. About 12 pounds per cubic foot were used for pine, and treated ties cost about three times as much as those untreated. It is said to contain 53.30 per cent of neutral oils (mostly paraffin oils), 36.70 per cent of tar acids, and 10 per cent of tar, and is also said not to soften the wood. In all kinds of creosote some engineers prefer the lighter and some the heavier oils.

In creosoting the sap should be thoroughly extracted, and if the oil is not well forced into the tie the wear of the rail may cut through and lead to decay of the unimpregnated interior of the tie. The natural decay also starts in the interior, which is not so thoroughly penetrated by the preservative. All cutting and forming of the timber should be done before treatment. The London and Northwestern Railway, England, employs a cylinder for the purpose of treating new cattle and freight cars entire (English cars being small and not more than 18 feet long). The details of operation vary. The Great Northern Railway (Ireland) and Lancashire and Yorkshire Railway (England), whose creosoting plants were described in my former report, both heat the oil to 120° F., but the former carries a pressure of about 100 pounds for three hours, while the latter carries 150 pounds for about fifty minutes.

There is considerable diversity of opinion as to the best kind of creosote, and, as above noted, some engineers prefer the lighter and some the heavier oils. The following is an extract from an editorial article on "Creosote specifications" in The Engineer, of London, September 25, 1891, dealing with the specifications for dead oil of coal tar:

> A glance at a few specifications for creosote used by Government departments, railway companies, and other large consumers will show that certain ideas are

common to most of them, and that such differences as there are rest rather upon diversities of phraseology and methods of testing than on any wide divergencies of opinion or requirement. Taking the clauses in the order in which they generally stand, one finds it laid down that the specific gravity shall be within certain limits. At the very beginning, therefore, an error is committed. No correlation appears to exist between the specific gravity of creosote and its quality, and if the limits are on this account put far enough apart to include all samples of good quality, the latitude is so great that the demand becomes meaningless. The clause might with advantage be abolished.

After the requirement as to specific gravity, a paragraph dealing with the amount of naphthalene and anthracene in the creosote usually occurs. Two methods of dealing with this point are in vogue. In the first it is laid down that when the creosote is cooled to a certain temperature—e. g., 40° F.—the amount of solid matter deposited shall not exceed a given percentage, such as 30 per cent. As may be readily understood, this is hopelessly inexact. The time factor is neglected altogether. Deposition of solid matter previously in solution in a liquid like creosote is by no means instantaneous, and a momentary cooling, although complying with the letter of the specification, will fail to afford any idea of the amount that would be deposited if the same temperature were maintained. Apart from its inaccuracy, considered as a prescription, the clause is faulty as attaining in a clumsy and imperfect manner what can be reached with ease and accuracy. The object being to prevent the presence of an undue amount of solid matter, such as napthalene and anthracene, the same end could be better attained by requiring that the creosote should be clear at the ordinary temperature or at some specified temperature rather than above this—e. g., 100° F.—so as to insure its being sufficiently liquid to be injected without difficulty. This is what is actually done in specifications adopting the alternative course referred to above. In addition to all this, it may be noted that the value of the solid constituents of creosote as preservatives is to some extent undecided, and there is reason to believe that a certain amount at least is distinctly desirable as being less likely to be lost by exudation than the liquid substances upon which reliance is generally placed. A specific action has also been attributed to naphthalene, not altogether without reason, but its volatility at ordinary temperatures makes its presence in considerable quantity of doubtful advantage.

The third clause with which we are concerned is often an ingenious example of the art of "how not to do it." It is quite common to find it specified that a certain percentage of the creosote shall distill below a given temperature. Seeing that the less volatile is the preservative, the more reason there is to expect it to be retained by the timber. This clause reads very like a self-denying ordinance, possibly heroic, but certainly inane. Rather should the demand be reversed, and a maximum fixed for the quantity distilling below a specified temperature, while a minimum percentage distilling between this temperature and the pitching point of the creosote might be required, so as to prevent the admixture of tar and similar matter not properly to be regarded as creosote at all.

The crux of the whole question is, however, to come. Every creosote specification demands that a certain percentage of tar acids shall be present, and the demand is enforced by many engineers with a good deal of rigor. At the time when most of the specifications now in use were drawn up it was universally believed that the whole preservative effect of the creosote was due to the tar acids it contains. Accordingly a certain minimum—e. g., 10 per cent—was laid down, and is retained to this day. Moreover, the tar acid, known to chemists as phenol, being considered most efficacious, it was further required that one-half of the total tar acids should distill below a specified temperature, the intention being to secure in this fraction a considerable proportion of the most active preservative. Advancing knowledge has shown that the preservative action of the class of bodies of which phenol is the type and first member has been much overrated, and it is doubtful whether the chief effect of creosote is not due to the neutral oil which constitutes its bulk, rather than to the

> comparatively small quantity of tar acids it contains. But, nevertheless, until this has been definitely proved the clause under discussion may well be retained as far as it relates to the total quantity of tar acids; but having regard to the fact that any greater preservative action that may be possessed by phenol will be more than counterbalanced by its greater volatility and solubility, the subclause dealing with the fractionation of the tar acids by distillation should either be struck out altogether or reversed, so as to prescribe the maximum that may be allowed to distill below a specified temperature. The alteration of specifications that have proved useful in their day should not be set about lightly or without reasonable cause; when the existence of that cause has been proved, alteration can not be too prompt and thorough. We believe that enough has been said to show that in specifications relating to creosote there is at least room for revision.

The specifications of the Great Northern Railway of Ireland require the creosote oil to be of the best quality, distilled from coal tar, and free from tar or other impurities. It must have a density or specific gravity as near to 10.50 as possible, the variation permitted being from 10.35 to 10.55; water being 10, and the temperature being 60° F. It must be completely fluid at 100°, and must not deposit crystals of naphthalene, paranaphthalene, or other substances when subjected to a temperature of 40°. It must yield to a solution of caustic potash not less than 8 per cent of crude carbolic and other tar acids. On trial by distillation only one-fourth is to distill or pass over at a temperature of 600°, and this fourth must be heavier than water. The Southern Pacific Railway has no fixed specifications for the dead oil, but simply exacts that it shall not have been treated for extraction of the aniline products, as it has been learned from the experience of others that dead oil treated for the extraction of chemical products after it was distilled did not seem to give good service when injected into timber.

The Lehigh Valley Creosoting Company states that the weight of the dead oil varies considerably, but that it tries to get an oil the hydrometer weight of which is as near 1.050 at 60° Fahrenheit as possible, which would make the weight 8.7 pounds per gallon.

The details of creosoting, as carried on at the Southern Pacific Company's works at Houston, Tex., as described in Mr. Kruttschnitt's statement, already referred to, are as follows:

> A vacuum of 22 to 24 inches is created (in the cylinder), requiring about 10 minutes. Live steam then turned in, destroying the vacuum, and giving a temperature in the cylinders of about 125 degrees Fahrenheit. This requires from 15 to 20 minutes. The vacuum pump is again started, and a vacuum is created to open the pores of the wood well, and to have the cylinders heated uniformly. This requires 15 to 20 minutes. Live steam is again turned on, and pressure raised to 30 pounds in about 40 minutes, being held at this from 6 to 8 hours, according to the size and kind of timber, care being taken to prevent the temperature from exceeding 250 degrees. Steam is then blown off, requiring 40 minutes. The vacuum pump is then again put into operation, and for the third time a vacuum of 24 to 26 inches is made, requiring about 90 minutes. While blowing off and obtaining this vacuum, and also during its continuance, the superheater is used to maintain a temperature of 225 degrees on the timber. The third vacuum of 24 to 26 inches is maintained from 4 to 6 hours, after which the cylinders are filled with creosote oil at a temperature of about 170 degrees. This requires about 35 to 40 minutes.

The pumps are then started and the pressure is raised from 80 to 100 pounds per square inch, and maintained from 1 to 2 hours, according to the kind and size of timber. The cylinders are then opened, after emptying them of the oil, and the train pulled out and another charge made in 40 to 60 minutes. The average time of treatment is from 18 to 20 hours; the average absorption, 1¼ gallons per cubic foot. The cost of this treatment has varied from $12.50 to $14.50 per thousand feet, B. M. The works have a capacity, when creosoting, of treating about 800,000 feet, B. M., per month.

It has been our experience with the woods treated with creosote oil that they are in no way softened by the process, if they are allowed to stand about six weeks after treatment before being put into service. This conclusion was arrived at in observing that the flange wear on ties before tie plates were used was not more than on untreated ties, and again, that spikes were driven with no more ease than with untreated ties.

The manner of gauging the quantity of oil put in the timber is as follows, the details given being of the practice followed at the creosoting works of Ricker, Lee & Co., at Galveston, Tex. These works have treated large quantities of heart yellow-pine blocks for street paving, the blocks being 5 by 6 inches section, 6, 8, and 10 inches long, specified to receive not less than 10 pounds of creosote per cubic foot, and the pavement is guaranteed for ten years. The cylinder is 9 feet inside diameter, 100 feet long, made of ½-inch steel plates of 60,000 pounds per square inch tensile strength, and closed by hemispherical doors. Each cage car holds 5,000 feet, B. M., of paving blocks loaded loosely, and six cars are run in at one time, making a charge of 30,000 feet. Two charges are treated per day, making a daily output of 60,000 feet, B. M. Each car has four wheels 18 inches diameter, running on 40-pound rails carried on brackets riveted inside the cylinder. The cars are hauled in and out by means of a wire rope and a winding engine. The doors are sealed by means of an annular rib on the face of the door, fitting an annular groove on the cylinder, in which groove is fitted a gasket of heavy canvas belting. The timber is heated or seasoned by passing steam (superheated to about 700° F.) through 6,000 feet of 1-inch heating pipe coils inside the cylinder, while a vacuum of 15 to 20 inches is maintained within the cylinder. The creosoted oil is then admitted, flowing through a 15-inch pipe from an elevated tank of 71,500 gallons capacity. This pipe opens into a 12-inch pipe under the cylinder, from which run four 8-inch branch pipes, leading to valves in the bottom of the cylinder. The cylinder is filled in six minutes, and more oil forced in by a duplex pressure pump until the timber has absorbed the required amount. The oil is then run out through the same pipes and by a 12-inch main to an underground tank of 8,000 gallons capacity, from which it is again pumped up to the storage tank. The doors are then opened, the cars hauled out, and another train run in from the opposite end.

To return to the matter of gauging the quantity of oil put into the timber, the practice followed at these works is as follows: A wire attached to a float on the inside of the storage tank leads to a gauge inside the building, which is graduated to feet and decimals, up to 20 feet—the depth of the tank. A table calculated for each decimal shows at a glance the number of gallons of oil represented by the index of the gauge. The exact contents of the cylinder and pipes leading to it from the tank being known, the load displacement, including cages, all reduced to gallons, is subtracted from this, the remainder showing space unoccupied in cylinder. To this space is added the number of gallons required to be absorbed by the timber, and the sum is the total number of gallons that must be put in the cylinder to fill it and force the required amount of oil into the timber.

The following is a copy of record as kept for each charge made:

Load No. 93—October 11, 1893—Wednesday.

		Gallons.
Cylinder space, empty		51,500
Displacement, 29,400 feet, B. M., blocks =	18,326	
6 cages at 16½ cubic feet = 99 cubic feet =	740	
		19,066
Cylinder space loaded		32,434
29,400 feet, B. M. = 2,450 cubic feet to receive 10 pounds oil per cubic foot = 24,500 pounds =		2,784
Oil required in cylinder		35,218
Gauge A, 13.25 =		47,361
Oil required in cylinder =		35,218
Gauge B, 3.40 (run back to 3,375.) =		12,143
Check:		
Gauge A, 13.25 =		47,361
Gauge C, 12.45 =		44,502
Oil actually put in blocks =		2,859

$\frac{2,859 \times 8.8}{2,450} = 10.27$ pounds per cubic foot put in blocks.

Vacuum on	7:45 a. m.	
Oil on	3 p. m	= 7¼ hours vacuum.
Pressure on	4:45 p. m	= 1¾ hours pressure.
Oil off	5:30 p. m	= 2½ hours oil.

Maximum vacuum, 13 inches; maximum oil pressure, 60 pounds; maximum superheater, 600°.

Gauge A represents oil in storage tank previous to filling cylinder. Gauge B represents the point to which gauge must be brought back to put the required amount of oil in blocks at calculated quantity per cubic foot. Gauge C is the standing of gauge after the oil has been run off the charge and returned to storage tank. The difference between gauges A and C shows the exact quantity of oil absorbed by the blocks. The difference, multiplied by 8.8, the number of pounds of oil in one gallon, and divided by number of cubic feet of timber in one charge, gives the average number of pounds of oil per cubic foot put in the timber.

The Central Railway of New Jersey laid about 4,000 creosoted Virginia pine ties in its main track near Bound Brook, N. J., in 1876, and in 1894 Mr. Olhausen, general superintendent, reported that 1,000 were still in use and in good condition. They were treated by contract with about 12 pounds of dead oil per cubic foot.

The New Zealand Government railways used various native and imported timbers up to 1885; but as the supply of the best qualities of the former diminished and prices increased with the demand for construction and maintenance, while the forests contained many timbers suitable for ties except in regard to their resistance to decay, the Government decided to try the creosoting process. In 1885 a contract was let for 150,000 creosoted ties at a little less than $1 per tie, the contractor arranging to erect the works. The cylinder was 66 feet long, and 6 feet 6 inches in diameter, with superheating pipes and rails for the cars. The charge consisted of 9 cars of 64 ties each, or 576 ties, fresh from the saw. When the air had been exhausted the cylinder was filled with creosote at 120° F.; superheated steam at 400° was then turned on, and the creosote kept at 212°, with a vacuum of 10 inches of mercury to draw off the volatilized sap. This was continued for fifteen hours, when communication with the vacuum tanks was closed and the temperature raised to 235 or 240°. The amount of oil absorbed being then ascertained by gauges, the quantity required to make up the specified amount of 18 pounds per tie (2 cubic feet) was pumped in at 10 to 50 pounds pressure. The time consumed over one charge was about twenty-three hours. The woods treated were as follows: "Rimu," or red pine (*Dacrydium cupressimum*); "miro," or bastard black pine (*Podocarpus ferruginea*); and white pine (*Podocarpus dacrydioides*). These absorbed about 12.4, 9, and 13.8 pounds per cubic foot, respectively; while the production of sap was 1.94, 1.41, and 2.16 gallons per tie. Ties put in the cylinder on Saturday had the sap extracted the same night, and were then allowed to remain in the oil until Monday morning. This resulted in a greater absorption, but the usual 50 pounds pressure was still required to complete the quantity to be forced in. It was considered that all boring and cutting should be done before treatment, as investigation showed that the heavier oil did not penetrate the middle portion or heart of the ties. After treatment the ties were stacked in long rows 15 ties high, so as to reduce the evaporation, and in order to lessen the danger from fire the tops of the rows were covered with 3 inches of soil.

The creosoting process is almost universally used in France, and creosoted beech ties on the Northern Railway of France have an average life of 27 years, and the Eastern Railway of France protects its creosoted ties from wear at the rail seats by means of felt plates. (See also the notes on the East Indian Railway, India, in Part I.)

BURNETTIZING.

This process (somewhat commonly known as the zinc-chloride process) consists in impregnating the ties with a solution of metallic zinc in hydrochloric acid, the methods of operation being similar to those for creosoting. It has been extensively used in Europe for about fifty years, and on some of the large Western roads in this country it has proved eminently successful. Burnettized hemlock and tamarack ties were laid in 1866 on the Chicago, Rock Island and Pacific Railway near Chicago, and in 1882, after sixteen years' heavy traffic, about 75 per cent were still in the track, and the rails had not cut them more than white oak ties. The Union Pacific Railway established works at Laramie, Wyo., at which the first ties were treated in 1866, and the last in 1887, the total number treated being 207,878. The ties were used for the most part on the Wyoming Division, and it is estimated that the treatment increased their life about three years. The Atchison, Topeka and Santa Fe Railway also has a plant of its own, using a solution of 1 pound of chloride of zinc to 4 gallons of water. The green ties cost about 12 cents each, and the treatment costs about $5 per 1,000 feet, B. M., or 25 cents per tie. The zinc solution, unlike creosote, should not be heated. The solution has the property of hardening the wood, but also affects its strength and elacticity, making it brittle, especially if too strong a solution (over 3 per cent) is used. The ties are said to be liable to split if exposed to a hot sun. The material in the ties after treatment is very soluble, and for use in wet or damp locations an auxiliary treatment to prevent leaching or washing out of the zinc is often resorted to, as noted further on. The details of the process as carried out at the works of the Southern Pacific Railway and described in the statement by Mr. Kruttschnitt, already referred to, are as follows:

> In the treatment of ties with chloride of zinc care is taken in charging the cylinders to fill them as nearly as possible with ties of the same age. This is to secure uniform treatment, for if green ties and ties that have been seasoned for about six months are subjected to the same treatment the percentage of absorption of the seasoned ties will be very much greater than the absorption by the green ties. The zinc solution contains 1.7 per cent of the chloride of zinc. This corresponds to 2½° on the scale of the Beaume hydrometer.
>
> First, a vacuum of 22 to 24 inches is created, this requiring about ten minutes. Live steam is next turned in, destroying the vacuum, and giving a temperature of about 125° in the cylinder. This takes fifteen to twenty minutes. The vacuum pump is again started and a second vacuum created, requiring fifteen to twenty minutes. In this way the pores of the wood are well opened and the cylinder heated uniformly. Live steam is then again turned on and the pressure raised to 30 pounds, giving a temperature of from 240° to 250° F. This requires about forty minutes. The steam is held at 30 pounds pressure for from three and one-half to six hours, according to the kind and condition of timber. Steam is then blown off, taking about forty minutes. The vacuum pump is again started and a third vacuum of from 24 to 26 inches obtained, requiring about ninety minutes. After this the cylinder is filled with the zinc solution, taking about twenty-five minutes, and the pressure is then raised to from 80 to 100 pounds, and held at this for from one to one and one-half hours, depending entirely upon the kind and the condition of the timber. The solution is then run off, taking about twenty minutes. The cylinder is next opened, the train pulled out, and another one placed in, ready to start again in forty to sitxy minutes from the time of opening the cylinders.
>
> The average time of treatment is from eleven to twelve hours. The cost of treatment of a tie 6 by 8 inches, 8 feet long, is from 9.5 cents to 12 cents. The average

These ties represented woods that would have lasted only from one to four years untreated; and in fact untreated ties laid at the same times as the above, and adjoining them, had all decayed and been taken up by 1891, when the treated red oak, black oak, and Colorado pine showed indications of an average life of ten to fifteen years.

The following particulars of the results obtained from the use of this process have been furnished me by Mr. Octave Chanute, C. E., who has had extensive experience in timber preservation:

Ties have been treated by this process at three works; (1) by the Atchison, Topeka and Santa Fe Railway, at its own works at Las Vegas, N. Mex.; (2) by the Union Pacific Railway, at its own works at Laramie, Wyo.; and (3) by the Chicago Tie Preserving Company (for the Chicago, Rock Island and Pacific Railway) at Chicago, Ill. The numbers treated each year were as follows:

Year.	Atchison, Topeka and Santa Fe Railway (Las Vegas).	Union Pacific Railway (Laramie).	Chicago, Rock Island and Pacific Railway (Chicago).
	Mountain pine.	Mountain pine and hemlock.	Hemlock and tamarack.
1885–'86	261,607	140,580	148,823
1887	320,922	101,889	254,188
1888	201,096		209,734
1889	241,871		210,169
1890	98,353		253,267
1891			840,431
1892			325,736
1893	175,035		406,154
Total	1,298,884	242,469	2,148,502

At Las Vegas and at Laramie the treatment has been chiefly confined to mountain pine, which absorbs the solutions very well. At Chicago, hemlock and tamarack have been treated. These woods are somewhat more refractory because of their closer grain. The cost of treatment varies from 17 to 20 cents per tie, according to size, amount of absorption, location, etc. This includes interest and repairs on plant.

In regard to durability, etc., the Atchison, Topeka and Santa Fe Railway reports that its tie renewals have been largely reduced by the treatment. In 1890 it abandoned the zinc-tannin process and treated its ties by the burnettizing process pure and simple, which is cheaper; but in 1893 it resumed the zinc-tannin process, and is operating it now. The Union Pacific Railway stopped operating its works in 1887, for financial reasons, and has not resumed, the works having been partly destroyed by fire. On the Chicago, Rock Island and Pacific Railway practically no ties treated by the zinc-tannin process were renewed until 1892, or after six years' service. In that year 2,319 were taken out, or 1.6 per cent of the 148,823 laid in 1886. In 1893 there were 14,282 renewed, this amounting to, say, 1.6 per cent on the 254,188 laid in 1887, and 7 per cent on the number laid in 1886. This indicates that there were yet 91.4 per cent of the latter ties in the track after seven years' exposure. The ties are materially hardened by the process, and are thought to resist cutting by the rail rather better than unprepared oak. Out of a lot of 50,200 oak ties laid by the Chicago, Rock Island and Pacific Railway on new track west of the Missouri River in 1886, a total of 7,616, or 14.56 per cent, had been changed in 1893, while out of 21,850 treated hemlock ties, laid at the same time, and on the same sections, 692 or 3.16 per cent, had been changed in 1893.

Some difference is found in results in consequence of the exposure; the treated ties being reported to do best in clay upland soil.

A detailed report is kept of each run, and the following is a specimen of the reports at the tie-preserving works of the Union Pacific Railway, at Laramie, Wyo., in 1886:

LARAMIE WOOD-PRESERVING WORKS—ENGINEER'S DAILY REPORT.

LARAMIE, WYO., *September 1, 1886.*

Runs 94 and 95.

	Run No. 95.	Run No. 94.
Cylinder No	2	1
First vacuum begun	Omitted.	Omitted.
12-inch vacuum indicated	Omitted.	Omitted.
	a. m.	*a. m.*
Begun steaming	8:50	7:55
18 pounds indicated	9:25	8:20
Blown off	11:25	10:20
Second vacuum begun	11:45	10:35
	p. m.	
14-inch vacuum indicated	12:45	11:35
Indicator $ZnCl_2$ tank	13.4 feet.	
$ZnCl_2$ introduced	12:50	11:40
		p. m.
100 pounds pressure indicated	1:10	12:10
Lowest point of $ZnCl_2$ tank	4.5 feet.	
Begun forcing back	3:40	2:40
Ended forcing back	3:55	3:05
Indicator $ZnCl_2$ tank	12 feet.	
Indicator vacuum tank	13.95 feet.	
Tannin introduced	4:05	3:10
100 pounds pressure indicated	4:10	3:15
Begun forcing back	5:10	4:15
Ended forcing back	5:25	4:30
Indicator tannin tank	13.8 feet.	

CHARGE.

Cylinder No. 1, hewn-pine ties	326
Cylinder No. 2, hewn-pine ties	336
Total	662
Reading of hydrometer, $ZnCl_2$ solution	2° Baumé
Reading of thermometer, $ZnCl_2$ solution	80° F.

(Signed) C. WALL, *Engineer.*

From these reports a daily statement was computed of the number of cubic feet of timber in each double charge, of their absorption both by volume and by weight, and of the percentage of pure chloride which has been consumed. This was obtained as follows:

Each cylinder was accurately gauged with 13 empty cars in it, and by reading the gauges on the solution tub at the lowest point reached, just before the surplus solution was forced back out of the cylinder, and also after it was all forced back, the displacement of each load was ascertained, and thus the number of cubic feet of ties in the cylinder was known.

The solution tank being also gauged by observing the reading both before and after each run, the total cubic feet of solution absorbed by the charge was also ascertained, and the strength being known it was easy to compute the amount of pure chloride absorbed. The mountain pine ties, which were chiefly operated upon at Laramie, were found to weigh 29.51 pounds per cubic foot. From these various elements the following table was computed, showing the results of the first month's operation:

Operations of wood-preserving works, Laramie, Wyo., from July 26 to August 31, 1886.

Date.	Run.	Charge.		Absorption of solution without glue.			Baumé reading.	Absorption of pure chloride.		
		Number of hewn ties.	Cubic feet of timber in charge.	Per cent by volume.	Solution heavier than timber.	Per cent by weight		Per cent of chloride in solution.	Per cent of chloride in timber by weight.	Total weight of pure chloride absorbed.
July 26	1- 2	804	2,976.8	13.68	*Times* 2.142	29.30	Gross. 2.05 Glue.. 0.17 Net... 1.88	1.44	0.42	368.95
27	3- 4	745	2,623.5	16.34	2.142	34.99	Net... 1.88	1.44	0.49	379.36
30	5- 6	692	2,623.5	16.34	2.142	34.99	Net... 1.88	1.44	0.49	379.35
Aug. 3	7- 8	651	2,709.7	18.98	2.141	40.65	Net.. 1.83	1.41	0.57	455.79
4	9-10	673	2,882.0	20.08	2.145	43.07	Net... 2.08	1.60	0.69	586.83
5 and 6	11-12	655	2,752.8	21.01	2.141	44.99	Net... 1.83	1.41	0.63	511.78
6	13-14	648	2,838.9	21.13	2.141	45.24	Net... 1.83	1.41	0.64	536.17
6 and 7	15-16	668	2,838.9	21.89	2.139	46.82	Net... 1.63	1.25	0.59	494.28
7 and 8	17-18	656	2,731.2	21.18	2.139	45.31	Net... 1.63	1.25	0.57	459.41
8 and 9	19-20	636	2,623.5	22.88	2.139	48.93	Net... 1.63	1.25	0.61	472.26
9	21-22	614	2,623.5	19.60	2.141	41.97	Net... 1.78	1.37	0.57	441.29
9 and 10	23-24	674	2,731.2	21.18	2.143	45.39	Net... 1.98	1.52	0.69	556.12
10	25-26	674	2,709.7	20.57	2.140	44.01	Net... 1.73	1.33	0.59	471.78
Totals and range.	1-26	8,790	35,665.2	13.68 to 22.88	2.139 to 2.145	29.30 to 48.93	1.63 to 1.98	1.25 to 1.60	0.42 to 0.69	6,113.37
Aug. 10-18	27-49	7,625	31,329.2	14.26 to 22.76	2.139 to 2.150	30.51 to 48.72	1.73 to 2.43	1.25 to 1.86	0.41 to 0.85	5,977.45
Aug. 18-26	50-75	8,642	35,807.3	18.48 to 24.34	2.140 to 2.145	39.61 to 52.05	1.73 to 2.08	1.33 to 1.60	0.58 to 0.83	7,250.91
Aug. 26-31:	76-93	5,949	24,990.3	18.59 to 24.24	2.141 to 2.145	39.83 to 51.90	1.83 to 2.13	1.41 to 1.63	0.59 to 0.77	5,087.91
Total and general average	......	31,006	127,792.0	20.79	2.142	44.53	Gross. 2.07 Glue.. 0.17 Net... 1.90	1.46	0.65	24,429.64 0.78 pound per tie.

NOTE.—We have reprinted in full but one of the form sheets, giving averages only for the other sheets, as more likely to serve the purpose required.

The operations at these works, as described in the Railroad Gazette, October 29, 1886, were as follows:

Metallic zinc was placed in lead-lined vats in the vat house (two being used to make the solutions and one for storage), and muriatic acid was poured over it. The result was a solution of chloride of zinc which stood at about 40° Beaumé. This was diluted with water until it stood at about 1.90° Beaumé, and a small percentage of dissolved glue (from a tank) was added, when it was stored in the chloride solution tub. A similar dilution of the extract of hemlock bark, or tannin, was made in the tannin mixing tub and stored in the tannin solution tub.

The ties to be preserved were then loaded upon the tramway cars, of which there were 100, running over the lines of tramway of 2-foot gauge, so arranged as to reach every portion of the tie yard. The cars were hauled by the wire rope, by means of the engine, into the cylinders.

These were 111 feet long and 6 feet diameter, and contained each 13 cars, loaded with, say, 350 to 400 ties, according to size.

The cylinder door was then closed hermetically tight, and the treatment commenced. This consisted in steaming the wood to liquify the sap, working a vacuum in order that the expanded air and steam might drive out as much sap as possible, and then injecting the two solutions successively under pressure. It was generally done upon the following schedule of time:

	H.	M.
1. Charging one cylinder		20
2. Raising steam pressure to 18 pounds		20
3. Duration of steam pressure	2	
4. Blowing off steam		15
5. Working vacuum	1	
6. Admission of chloride solution		15
7. Duration of pressure (100 pounds)	2	30
8. Forcing back chloride solution		20
9. Admission of tannin solution		10
10. Duration of pressure (100 pounds)	1	
11. Forcing back tannin solution		20
12. Discharging one cylinder		20
Total time occupied	8	50

It will thus be seen that the treatment occupied about 9 hours, the the object being to inject the wood as completely as possible with the chloride of zinc, and then to close the outer sap cells with the tannin, which upon coming into contact with the glue of the first solution forms pellicles of artificial leather, which act as diaphragms, and so prevent the zinc from washing out. The principal effort was to inject as much of the zinc chloride solution into the ties as practicable. When the works were first started experiments were made to test the comparative absorption of various ties, by weighing them before and after treatment, and they were found to absorb all the way from 12 to 91 per cent of their original weight, according to the closeness of the grain or the amount of sap remaining in the cells.

The Atchison, Topeka and Santa Fe Railway has (as already noted) works at Las Vegas, N. Mex., for the treatment of ties and timber by the zinc-tannin process, and the following description of these works is taken from an article in Engineering News, New York, September 13, 1894:

> There are two cylinders, 6 feet inside diameter and 106 feet long, opening at one end only. A narrow-gauge track is laid in the yards and within the cylinders, and the iron cylinder cars or cages are hauled in and out by a duplex hoisting engine and wire cable. Storage and mixing tanks, storehouses, etc., are provided.
>
> A very large percentage of the timber treated consists of hewn ties of native or mountain timber. They are unloaded from the cars at the spotter on to an endless platform, which carries them through the saws, where the ends are sawed off and the faces scarfed to give the rails an even bearing. As the ties drop from the endless platform they are loaded on to the cylinder cars and passed along to the cylinders,

where the treatment is given, requiring about ten hours. They are then drawn on to the elevated platform, where they are loaded into railway cars for shipment.

The maximum number treated in any one month so far is 45,000, but the average falls greatly below this figure. The plant is not provided with appliances for creosoting. Only the chloride of zinc treatment is used. Usually the Wellhouse or tannin method is employed, but the simple burnettizing process has also been tried. The following sample report of the engineer in charge will give an idea of the process in treatment:

Las Vegas Wood Preserving Works.

No. ——.] [Date, April 23, 1894.

No. of run.	No. of cylinder.	First vacuum commenced.	12 inches indicated.	Commenced steaming.	18 pounds indicated.	Blow off.	Second vacuum commenced.	14 inches indicated.	Indicator zinc tank.
6059	1	7:20	7:30	7:30	8:10	12:20	1:20	2:00	14.00
6060	2	8:20	8:30	8:30	9:50	1:20	2:20	3:00	14.00

No. of run.	No. of cylinder.	Chloride zinc introduced.	Indicator lowest point.	Forced back.	Indicator zinc tank.	Indicator tannin tank.	Tannin introduced.	Forced back.	Indicator tannin tank.
6059	1	2:00	3.80	4:30	12.25	14.00	5:00	6:30	13.80
6060	2	3:00	3.80	5:30	12.25	14.00	6:00	7:30	13.80

Thermometer, 90; strength, 0.015; absorption, 0.31; hydrometer, 150; displacement, 2,398.2.

(Signed) —— ——, *Engineer.*

The indicators are read and figures made for double runs on two cylinders together. The displacement or cubic contents of the material in the run is found by taking the number of cubic feet of solution forced back and deducting this from the cubic contents of the cylinders, less the volume of the empty cylinder cars. In the above case we have cubic contents of cylinders $6 \times 6 \times \frac{1}{4} \pi \times 212 = 5{,}994.17$ cubic feet. Volume of 26 cylinder cars at 1.807 cubic feet each $= 46.97$ cubic feet. Solution forced back: Indicator zinc tank $12.25 - $ lowest point $3.80 = 8.45 \times 420$ square feet (area of tank) $= 3{,}549$ cubic feet, whence $5{,}994.17 - 46.97 - 3{,}549 = 2{,}398.2 =$ displacement.

The percentage of absorption of the zinc solution may be found by dividing the quantity of the solution introduced by the volume of the material treated. In the above case it is $(14 - 12.25)\ 420 \div 2{,}398.2 = 0.31$ nearly.

Steam is furnished by two 60-horse-power boilers, and the blocks sawed from the ends of the ties constitute the greater part of the fuel. The plant is also equipped with a stationary engine, with cylinder 10 by 14 inches, for running the saws; a hoisting engine, a Knowles duplex air pump with steam cylinders 6 by 10 inches, and two Worthington duplex force pumps, with cylinders 3¼ by 6 inches. Besides several cooking and mixing vats, there are two storage tanks, one for zinc solution and one for tannin, 16 feet high, and with an area of cross section of 420 square feet.

Chemicals are received in car-load lots from works in Eastern states. They are mixed in the various vats to a solution of the proper strength (0.015 per cent for zinc and 0.005 per cent for tannin) and forced into the storage tanks by means of a steam ejector pump. Glue is added to the zinc solution at the rate of about 2 pounds of glue to 100 gallons of solution. The strength of the zinc solution is tested in the storage tank with the hydrometer after each run and restored to the proper standard by additions from the mixing vat.

The strength of the tannin solution is maintained by additions proportional to the amount of tannin solution absorbed, plus the absorption of the zinc solution in the same run. The tannin being introduced subsequently, is robbed of its strength by the zinc which it finds in the timber.

The solution is drawn from either tank to either cylinder through 8-inch pipes by exhausting the air in the cylinders. Pressure is maintained through the Worthington pumps. The solution is forced back to the tanks by air pressure through the 8-inch inlet pipes or through 4-inch overflow pipes. There are more than 300 valves of various kinds and sizes in and about the works.

The works have not been run continuously since installation, but have usually closed down during the winter months. The total amount of material treated up to the beginning of 1894 (reducing piling and other timber treated into its tie equivalent by allowing at 4 cubic feet per tie) is 1,853,839 ties, at an average cost for labor, chemicals, and fuel of 14.94 cents per tie. No account is made of interest or depreciation of plant.

The cost of treatment has somewhat decreased since the installation of the plant, owing partly to the decreased cost of chemicals and labor, and partly to greater efficiency gained by extended experience. The cost for the month of June, 1894, was but 10 cents per tie. It is to be understood that such calculations as here given must be considered only as giving a general idea of the relative cost of the various processes, to be modified in every particular instance by the varying conditions under which the works may be placed, varying also with the kind of wood operated upon and the price of fuel, chemicals, etc.

The results so far have been fairly satisfactory, although some of the treated ties are now being removed on account of decay. Many, however, of those treated in 1885 are still sound. It is believed that the results would be far better if the railway company did not pursue such a "hand to mouth" policy. The timber does not have time to season before treatment, nor time to harden before being put into service. This year contracts for timber were awarded in Chicago on January 10. By April 10 the wood-preserving works were running on freshly cut timber, and before May the newly treated ties were going into the track. It is believed that if the timber were allowed to season thoroughly before treatment and to harden thoroughly before using a life of fifteen years might reasonably be expected for the average tie. The lack of economy resulting from such a policy has already been referred to. The works are operated by the railway company, under the supervision of the division superintendent. They were established in 1885.

VULCANIZING.

This process, based on various patents taken out in 1871 and 1891, consists in heating the timber in cylinders to a temperature of 300° to 500° F. under an air pressure of 100 to 175 pounds per square inch, by which it is claimed that the chemical condition of the sap may be changed into a preservative composition. A later patent (1893) claims the same result by substituting a vacuum for the pressure and a low temperature to effect the same result, namely, to "vulcanize" the wood. It has been mainly applied to Georgia pine, at a cost of $8 per 1,000 feet, or 25 cents per tie, and Col. Hain, general manager of the Manhattan Elevated Railway (New York), has reported satisfactory results from ties and guard timbers treated by this process since 1884. Other timbers have been treated, and a number of railroads (including a number of street railways) are reported as using the vulcanized ties. For a somewhat fuller description see Bulletin 4, pp. 30, 31. There is no knowledge of the physiology or chemistry of wood to sustain the claim of the chemical changes, nor has the material been long enough on trial to prove by experience the value of the process. Tests of treated and untreated material of such nature as to make the material comparable otherwise, made by the Forestry Division, did not show any increase in strength, as claimed, nor any chemical or physical changes.

BOUCHERIE PROCESS.

The timber is impregnated with a solution of 1 pound sulphate of copper to 100 pounds of water, either by pressure in a closed cylinder or by applying a cap with pipe connections to one end of the tie or log and forcing the solution through by pressure or vacuum, about eighty to one hundred hours being required for it to traverse a log the length of a tie. Contact with rails and spikes is said to decompose the solution, producing free sulphuric acid, which attacks the fiber and weakens the timber, but in Europe the process is said to have increased the life of pine ties from seven to fourteen years.

KYANIZING PROCESS.

The ties are steeped in a solution of bichloride of mercury (corrosive sublimate) in the proportion of about 1 part of bichloride to 100 parts, by weight, of water (or 1 pound to 8 or 10 gallons). The time is about one whole day for each inch of thickness, or, say, ten days for timber 8 inches thick. The solution is an active poison and the material must be handled carefully. The process hardens the wood, but is found in general to be more satisfactory for timber in dry situations and exposed to the air than for ties laid in ballast and kept moist. The Boston and Maine Railway used kyanized hemlock ties at one time and found them economical when the treatment was well done.

Full information regarding the "kyanizing" process, i. e., steeping the wood and impregnating it with bichloride of mercury, have been given in Bulletin 1 and the efficacy of the process has been pointed out. A reprint of the statements then made will be found on page 78 of this report.

In addition it will be of interest to quote the following statement, made by Mr. Charles H. Allen, of Lowell, Mass., with reference to the experiences of the Massachusetts Locks and Canals Company. He writes, under date November 19, 1894:

> As their (the company's) purpose in using that process was entirely removed from any interest in any process, as such, but simply to employ what was best, their continued use of this process is valuable testimony to its efficiency, so far as their requirements were concerned.
>
> And more than this, after the company had used the kyanizing process for two years (1848-'50) they were attracted to the burnettizing process, thought then to be quite as effective as kyanizing, and much cheaper, because of the chemical used (chloride of zinc) and with a good deal of saving in time, because the lumber was treated in large iron cylinders, by first exhaustion, then forcing the solution into the wood under pressure.
>
> This process, Mr. Francis says, was carried on by his company for twelve years. Thus they have lumber in the mills and bridges, artificially preserved by two proc-

esses—kyanizing carried on by them from 1848 to 1850, and burnettizing from 1850 to 1862. After their experience of fourteen years, they returned to kyanizing, as much more effective for their uses than burnettizing, and they have followed the former process continuously to this time, and they have no intention of attempting to use any other process. Their experience of nearly half a century has convinced them of the usefulness of the process of kyanizing.

In 1862 Mr. Francis decided to make further experiments of the kyanizing process for the benefit of his company. He felt that up to that time, while their experiments had all been made in a practical way, by simply treating the lumber, dating it, and using it where it was wanted and observing results, still the kinds of lumber used had been very limited in number. So he had twelve specimens of the various kinds of wood grown about here, and used more or less extensively for building purposes, prepared. The specimens were all sawed at a mill here in Lowell, and were each 18 feet long, 9 by 9 inches, thus:

1. Old growth white pine, 18 feet long, 9 by 9 inches.
2. Sapling white pine, 18 feet long, 9 by 9 inches.
3. Northern hard pine, 18 feet long, 9 by 9 inches:
4. Spruce, 18 feet long, 9 by 9 inches.
5. Hemlock, 18 feet long, 9 by 9 inches.
6. Birch, 18 feet long, 9 by 9 inches.
7. Black birch, 18 feet long, 9 by 9 inches.
8. Yellow birch, 18 feet long, 9 by 9 inches.
9. Rock maple, 18 feet long, 9 by 9 inches.
10. White maple, 18 feet long, 9 by 9 inches.
11. Brown ash, 18 feet long, 9 by 9 inches.
12. Poplar, 18 feet long, 7 by 7 inches.

These specimens were sawed in the summer of 1862. After being numbered as above, the pieces were cut in two, and one-half of each was kyanized, and the other half retained in its natural state.

In the following spring, that is, April 29, 1863, they were set in the open ground as posts, in two rows, about 4 feet of their length in the ground, and about 5 feet out. These posts remained in the ground, without being disturbed at all for twenty years. Then, on May 1, 1883, they were taken up for the purpose of cutting off the specimens which were exhibited at the National Exposition of Railway Appliances, held at Chicago in May and June, 1883. These specimens were all taken from near the ground line. The original specimens were then put back in the same holes, the dirt filled in again about them, and they are standing today (November, 1894) with the kyanized specimens very well preserved, practically sound, while the unkyanized parts have about all rotted away, and the remains are encased, in order to indicate where they stood and what they were. All the original specimens have been fully exposed to the weather for thirty-two years. They stand in rows about 2 feet from the northwest side of a building, the unprepared row being nearest the building and the kyanized row about 6 inches front of them, all being about 9 inches apart in the row. The soil is coarse gravel, rather binding, containing no clay, and is drained by the cellar of the neighboring building, the walls of which are laid without mortar.

This remarkable exhibit seems to establish beyond question the efficiency of the process of kyanizing. Claimed by no one as capable of making lumber last forever, nor of making unsound timber sound, but confidently recommended as of sufficient value, under nearly all circumstances, to encourage its very general use.

The fact is that the experiments in this direction in this city are not only unique, but are more practical and extensive, I believe, than have been attempted elsewhere, at any time in this country. The character and intelligence of the men conducting these experiments at once commend the accuracy of their work, and the fact that the corporation undertaking them has been a very conservative body, with a degree of permanence in the personnel of its officers, such as to warrant long series of uninterrupted experiments, has also been in favor of good results.

My interest in this matter arises from the fact that I have known of these experiments by the Locks and Canals Company for many years. And while they have used them for their own benefit, as they could not, if they cared to, under their charter as a water-power company, undertake to carry on the process of kyanizing for the public, I have felt that the value of the process should be more generally known. And if it would double the life of timber perhaps in its use alone the questio of the preservation of forests would be more aided than by all the legislation sought, or likely to be enacted.

The charge for kyanizing varies with the price of the bichloride of mercury, and that varies with the price of quicksilver; but at the end of 1894 the charge was at the rate of $8 per 1,000 feet, board measure, for lumber of all kinds, and $1 per thousand for shingles, besides additional charges of 25 cents per 1,000 feet, board measure, for unloading and 25 cents for reloading lumber received at the works by rail. The firm states that it has kyanized several million feet of spruce timber, 5 by 7 inches, for stringers and ties for street or surface railways. Mr. P. F. Sullivan, general manager of the Lowell and Suburban Street Railway Company, states that in preparing to change from animal to electric traction the question of the use of treated timber in track construction received careful attention, as a result of which over 1,000,000 feet of kyanized spruce was used in 1892 with satisfactory results. In cutting the treated timber with the ax or adze it was found to be very tough and hard, which is one of the results claimed for this process.

It will be noted from the statement on page 78 that the cost of the process appears considerably greater than that of the chloride of zinc or burnettizing process, which seems to have sustained its reputation for efficiency fairly well, and this question of cost will have to be taken into account when the two processes are compared.

THILMANY PROCESS.

The ties are placed in a cylinder and impregnated first with a solution of sulphate of copper (or zinc), under 80 to 100 pounds pressure, and then with a solution of chloride of barium, forming a chemical combination of insoluble sulphate of baryta and chloride of copper (or zinc). Tests made by Mr. A. M. Wellington on the New York, Pennsylvania and Ohio Railway, in 1880, with different kinds of wood treated by this process, showed a decided loss of strength, but there was no reduction in the holding power of spikes.

MISCELLANEOUS MINOR PRESERVATIVES.

There are on the market a number of preservative compositions to be applied like paint and used on car and bridge work, etc. They should not be used on any but well-seasoned timber.

Fernoline (Fernoline Chemical Company, N. Y.) is a compound of creosote, paraffin, and oil of tar. It has been used for car timbers, bridge and station timbers, etc., to prevent decay and the attacks of the teredo navalis and other boring worms. It may be applied with a brush, or the timber may be soaked in it.

Spirittine (Hansen & Smith, Wilmington, N. C.) is obtained by the destructive distillation of pine and cedar, and may be applied with a brush. It has been used mainly on yellow pine. Cross-ties soaked in it are said to have had an increased life. It meets the requirements of the Pennsylvania Railway specifications for wood preservatives, and analysis shows 64.25 per cent of tar acids, 30.75 per cent of neutral oils, and 5 per cent tar. It is said not to soften the wood.

The Finch preservative (Finch Wood Preservative Company, Toronto Canada) has been used for sidewalk planking and paving blocks with satisfactory results. The wood is immersed in the solution and then stacked to dry. Some of the sidewalk planks lasted seven years and were then in condition to be turned. It has been used by the Grand Trunk, Canadian Pacific, Intercolonial, and Michigan Central railways, and by the cities of Toronto, Winnipeg, etc. The preparation is said to mix with the sap and make a preservative compound preventing interior fermentation.

The Pennsylvania Railway specifications for wood preservative (including fernoline and spirittine) state that the material desired is a product of the distillation of Georgia pine containing as large an amount as possible of the preservative acids characteristic of this distillate. It must show the following results on testing:

Flashing point ... degrees F..	200	Specific gravity	1.05
Burning point ... do....	220	Tarry matter ... per cent..	5
Temperature at which material will run ... degrees F..	15	Tar acids ... do....	45
		Neutral oils ... do....	50

Material will not be accepted which flashes below 172° F.; burns below 200°; will not run at 20°; specific gravity less than 1.03; has more than 12 per cent of tar or less than 30 per cent of tar acids. The instructions for use are as follows:

(1) Wood preservative will be used on all tenons and in all mortises in both passenger and freight car work, and in the woodwork of tenders and cabs (except as specified in sections 5 and 6). The skeletons of passenger equipment cars should be coated with wood preservative instead of with freight-car color, as formerly, except where glue is used in making joints. The backs of panels should be coated with freight-car color. If the piece of wood is small it is well to dip the tenon in the liquid. In all other cases it should be applied with a brush, and care should be taken to have as much of preservative taken up by the wood as possible. The shoulders of the tenons and the shoulder seat should be included in the treatment, as it is found that the water which gets in between the shoulders and shoulder seats causes rapid decay in these places.

(2) In all passenger, freight, tender, and cab work where two pieces of wood touch each other, and glue is not used in making joints, at least one good coat of the

preservative must be interposed, except in the joints of the siding and roofing and as specified in sections 5 and 6. The roofs of cabs must have at least two coats before the tin is put on.

(3) The floors and tops of all stringers and end sills of all stock, gondola, and flat cars, and of cars engaged in the manure trade, and the skeletons of all tenders before the floor is laid, and all that part of the tender floor which is covered by the cistern, must have at least two good coats of wood preservative. It is also recommended to use wood preservative on tenons and in mortises of shop buildings, and all over floor timbers and on underside of flooring, especially where the ground is damp and ventilation poor.

(4) On the floating equipment the preservative should be used freely. All parts of the hull which are submerged should have at least one good coat, and it should be used on tenons and in joints everywhere where it will not interfere with the paint, as described below. The decks of ferryboats under the sheathing, and the sheathing itself, should have not less than two coats.

(5) On wood that has been treated with the preservative it is found that paint dries very slowly, and great care should be taken not to use it or permit it to get on surfaces that must be painted.

(6) In those situations where, from the construction employed or from the protection afforded by the paint, water can not get at the woodwork the preservative need not be used as above directed, but, being a preservative, it is better to use it where it is not actually needed than to allow any part that does need it to escape.

(7) If the wood preservative when received is too thick for use, as may happen in cold weather, it may be thinned with spirits of turpentine.

For protecting rough timber, such as the cut heads of piles, etc., tar is better than applications of hot creosote, as it affords a mechanical as well as chemical protection. The cheap resin now thrown away at the turpentine distilleries in the South would be an excellent and cheap material for treating the ends of ties (a cheap method of arresting decay) or for filling old spike holes. Tar is also used to some extent for filling such holes.

According to F. Engel, government surveyor of buildings (Germany), painting wood with carbolineum as a protection against the weather and rot gives favorable results. The Imperial Government surveyor of buildings also confirms this statement in a certificate under date of January 19, 1885, in which he states that on the imperial roads woodwork used in underground construction during the years from 1870 to 1885, when painted with carbolineum, had no decay up to date of certificate. For the sake of experiment two pieces of pine wood, taken from the same plank, were thus treated: The first was painted with carbolineum, while the second was left in its natural state, and both placed in the ground under the same conditions. At the end of three years the painted specimen was found to exhibit no signs of decay, but the unpainted one was in a rotten state.

The district surveyor of buildings inclines very favorably to the use of carbolineum on buildings in the water, and on sluice gates, dam barriers, piles, posts, especially when the wood is kept wet or dry, or by turns wet and dry. It is found that carbolineum is cheaper than the semifluid tar. For an area of 6 square meters 1 kilogram of carbolineum is ordinarily used; and its superiority over tar is shown by the fact that even the largest manufacturers, where tar is a by-product, and the use of which costs nothing, are coming to use carbolineum.

It is best and most advantageous to paint with hot carbolineum, for in this state it is more fluid than when unboiled, and for this reason penetrates into all cracks and openings, at the same time dissolving any rosin or oil present; it also disinfects more energetically in a warm state than in a cold one. In warm weather, and on wood when the surface is not buried in the earth, it is necessary to give a thicker coating of the unheated oil, especially as it can be repeated after a while. Wood that is not completely air dried must always be treated with hot carbolineum. All the wooden posts of bridges that are exposed to changes of wet and dry, as well as their gravel-covered layer of planks, are painted with two coats of hot carbolineum. All knotty wood surfaces must be very carefully treated, applying only so much as will be readily absorbed. The knotty surfaces of wood being the places where the ducts open, these are thus the very localities where the decay and destruction from lower organism begin, and it is on this account that they must receive special protection. One kilogram of carbolineum (which comes in casks of about 200 kilos each), costs 0.3 marks=7 cents.—(*B. E. Fernow, Bulletin No. 1, 1887.*)

METAL TIE-PLATES.

General Remarks.

With wooden ties the rails usually give considerable trouble by cutting the ties at the rail seats, thus decreasing the hold of the spikes, allowing the rails to tilt on curves, and rendering the ties unserviceable. Direct pressure of the rail on the tie would have no effect beyond a very slight compression of the wood, but the cutting and wearing is due to the slight motion of the rail, grinding and abrading the fibers, and so greatly facilitating local rot and a softening which hastens the cutting effect. The rotting also affects the spike holes, thus diminishing the holding power of the spikes and endangering the safety of the track. One of the most important and practical of modern improvements in railway track has been effected by the wide introduction of metal tie plates between the rail and tie, which involves only a small first cost, but effects a most decided economy in ties and track work. Their cheapness, combined with their undoubted advantages, has led to their extensive adoption on many hundreds of miles of track, as it is recognized that they not only increase the life of soft (and cheap) though durable ties, but effect a direct economy in renewals and maintenance of way, while adding to the permanence and security of the track by giving a durable and uniform bearing to the rails and lessening the disturbance of the track for tie renewals. On steep grades they prevent the increased cutting of the ties by sand from the engines getting under the rail and acting to abrade the wood. They also prevent widening of the gauge by the tilting of the rail resulting from the outer edge of the flange cutting and sinking into the wood, which is a great trouble on curves; and they tend to reduce the wear of the spike, especially if the plate has a rib or lug to take the outward thrust of the rail flange. They should be large enough to give a good bearing on the tie, with room for the spike holes, and stiff enough to prevent bending or buckling. Plates 12 by 12 inches, ½ and ⅝ inch thick, have been found too large, tending to cause the tie to rock. When tie plates are put on old ties a flat seat must be adzed for each plate, or the plate will be buckled through having an uneven bearing. In some cases where put on old ties they are said to have effected a saving of 50 to 75 per cent in track work for maintaining the gauge. When first introduced it was predicted that they would make it difficult to keep the track to gauge, but, as a matter of fact, the very opposite has been the result, as they not only prevent the tilting or overturning motion of the rails, but also hold the inner and outer spikes together, so that they both act to resist any bodily forcing outward of the rail. On curves they have been successfully used in place of rail braces for the above reasons, as the great trouble (especially on sharp curves at switches and turn-outs) is the tendency to overturn the outer rail. The fact that some tie plates have met with marked success has naturally led to the patenting of various modified designs of such plates.

Thin flat plates were first used, but these were apt to buckle and crack, and, being comparatively loose on the tie, they held the water and churned it into the tie, causing local rot, while the loosening of the ordinary spike fastenings led to a disagreeable clattering under the trains. The New York elevated railways laid some flat tie plates, 6 by 8¼ inches, in 1888, but in addition to buckling and cracking at the ends they induced premature decay of the wood (yellow pine) under them. They jumped and rattled under passing trains, and thus in wet weather forced the water into the wood and kept it wet, hastening the rot, especially, in summer, when the tie plates were hot and the ties damp. In less than six years these ties were removed in various stages of decay on account of the rotting under the plates, at the part where soundness is most required. In some ties the rot extended to the sap wood beyond the plates, while in heartwood it was confined to the part covered by the plates. It is not necessary to use a very wide plate, as it does not accommodate itself to the wave motion of the rails, and experiments made with a bearing the full width of the tie showed that it caused the tie to rock in the ballast. In order to unite the plate firmly to the tie various arrangements of teeth, ribs, and flanges on the bottom of the plate have been tried. Some of these plates have ribs transverse to the fiber of the tie, and thus sever the fibers, while others have the ribs or flanges approximately parallel with the fibers. The ribs should do as little damage as possible to the surface of the tie, while securing a firm hold in the wood. The Eastern Railway of France uses felt plates to protect the rail seats of creosoted ties.

The economy resulting from the use of the tie plates will necessarily depend upon the price and life of ties, the price of the plates, etc.; but the following is an approximate estimate of the comparative economy with cedar ties lasting six years without plates:

Track expenses (without tie-plates).

2,640 ties, at 30 cents	$792
Cost of laying, at 10 cents per tie	264
Ties and labor	1,056
Renewals at same price	1,056
Total for twelve years	2,112

Track expenses (with plates).

Ties and labor, as above	$1,056
5,280 tie plates, at 15 cents each	792
Total for twelve years	1,848
Deduct scrap plates, half original weight, at 1 cent per pound	120
Net total	1,728

Summary.

Cost per mile for twelve years:	
Without plates	$2,112
With plates	1,728
Saving per mile, by plates	384

Another economy, however, is in the daily work of maintenance, owing to the reduction of the work of respiking, correcting gauge, tamping loose ties, etc.

AMERICAN TIE PLATES. (*See* Pl. 3.)

The following are the principal plates used in this country, but in addition there are numerous other plates which exist only on paper, or have been tried on a very limited scale:

Churchward tie plate.—This plate has on the upper side a rib to take the thrust of the rail flange and on the lower side six blunt teeth of V section which cut across the fibers. The plate is of rolled steel, and has at first two ribs on the underside which are formed into teeth by passing the plate through rolls having pockets instead of grooves. The teeth are about 1 inch long and three-eighths inch high, while the upper rib is one-fourth inch high. The plates are 8 or 9 inches long (lengthwise of the tie), 6 inches wide, and about one-fourth inch thick, and the weight is 4 pounds per plate. The teeth are shorter on the edge than on the base in order to wedge themselves into the wood, and it is claimed that no water can get in, especially when the plate is flat upon the tie. (Central Oil and Supply Co., New York, N. Y.)

Goldie tie plate.—This is a steel plate with two ribs of V section on the underside cutting across the fibers, and a rib on the upper side to take the rail flange. The ribs are the full width of the plate, and are intended to resist lateral shifting of the plate, while it is claimed that water can not get in around them. The upper rib relieves the outer spike from the abrasion and wearing by the rail. The plate is of rolled soft steel, one-fourth inch thick, and is 8½ inches long and 4 to 6 inches wide. Another form of this plate has a chisel-edged lug at each corner to bite into the tie, instead of the two ribs. (Dilworth and Porter, Pittsburg, Pa.)

Holgate plate.—This is a flat-bottom plate, 7 by 8 inches (8 inches across the rail), nine thirty-second inch thick, and weighing 4 pounds. A lug is stamped up to fit over the rail flange, the plates being laid alternately with the lugs on the inside and outside of the rail. They were laid in 1888–'89 on 500 cedar ties with 65-pound rails, and on Norway pine ties on several bridges on the Grand Trunk Railway. In March, 1894, Mr. Holgate (Peterborough, Ontario, Canada), wrote me as follows:

> About 1,000 plates were laid continuously on 500 ties. I have made inquiry and the roadmaster of that district writes me to say that the cedar ties on which the tie plates rest are "as good as ever," and he says there is every probability of their lasting many more years. The ties for a quarter of a mile on each side of this batch of 500 are also cedar and were laid at the same time. These, the roadmaster says, will have to be taken out of the track early this spring, as they are "worn out." The question as to economical results I can not answer, not now being in the employ of the Grand Trunk Railway, but I think that my experiment in connection with tie plates was the only one made on the railway. I may say that on the floors of several large bridges I also used the tie plate, but the timber (Norway pine) being harder, the good effects of the plate is not yet so plain as on the softer wood.

Servis tie plate.—This is one of the most extensively used plates and consists of a rolled steel plate with the sides turned down to form flanges which lie lengthwise of the tie. The plates are thus of channel section, but the larger sizes have one or two intermediate ribs, thus stiffening the plate and serving to hold it firmly to the tie when the flanges are driven into the wood, compressing the fibers between them so that there is no motion of the plate to cause rattling or abrasion. The smaller plates are 3¾ by 8 inches, with two flanges, and the larger ones, with three flanges seven-eighth inch deep; one 6 by 9 inches. The larger ones are used at joints (as on the middle tie of the 3-tie joint of the New York Central Railway), on soft ties with heavy traffic, or where extra spiking is required, as on sharp curves and heavy grades. These plates were laid on some oak ties on the Louisville bridge of the Pittsburg, Cincinnati, Chicago and St. Louis Railway, which ties were badly cut by the rails, but otherwise sound. For four years little or no work was done, although formerly three men were kept almost constantly shimming, lining, and correcting the gauge, redriving the spikes, etc. In 1893 several of the ties were rotting beyond the rail seats, but the plates were still affording ample support to the rails, carrying a traffic of 150 trains per day. On this and other bridges and on some 6° curves the saving due to the use of the plates is estimated at 50 per cent in ties and 60 to 75 per cent in labor. The Servis plate is also made with a rib across the upper side, the rib being cut away for the width of the rail base and serving to resist the thrust of the rail on both inner and outer side of the base. (Q. and C. Company, Chicago, Ill.)

In July, 1892, Mr. P. S. Archibald, chief engineer of the Intercolonial Railway of Canada, wrote me as follows in regard to the Servis plates on that road:

> The first two or three lots we found rather light, and a considerable number of them bent up at the ends. This trouble, however, I think was a good deal owing to the fact that the bulk of them were used on old ties considerably worn under the rail flange, and the section men, I fear, were not particular enough when adzing the

ties to make a perfectly level bed for the plates. Where used on new ties they were much more satisfactory. The increased cost of the heavier plate is so small we determined to adopt it. On the northern division of our line we get cedar ties very cheap (from 13 to 16 cents each). Without the plates they were out in about four or five years, but with the plates we expect them to last at least twice as long. We find that the holding power of the spikes is largely increased by the use of the plates, which is a very important matter. The tendency of the track to spread on cedar ties was the greatest objection to their use. We use a longer plate for the rail points on account of the angle fish plates. Our rails are 4⅛ inches high, 4½ inches flange, and weigh 67 pounds per yard. Everything considered, our experience with Servis tie plate has been very satisfactory. Our ties come so cheap, however, in this country (from 13 to 18 cents each for cedar, tamarac, hemlock, and prince's or Norway pine) that there is not the same inducement to use the plate as there would be if the ties cost 30 to 50 cents each, as they do with you. They are not the least noisy in riding over them, as some predicted they would be. The first plates we used were three-sixteenths inch thick, with flanges seven-eighths inch deep.

The heavy plates referred to by Mr. Archibald are 3¾ by 8 inches for intermediate ties and 3¾ by 9⅝ inches for joint ties. The former have two spike holes three-fourths inch square, 4$\frac{7}{16}$ inches apart, with the center 1 inch from opposite sides of the plate. The latter have two spike holes three-fourths inch wide and seven-eighths inch lengthwise of the rail, 5$\frac{15}{16}$ inches apart, and fifteen-sixteenths inch from the edges. Both plates are one-fourth inch thick, with two flanges three-fourths inch deep, making the plate 1 inch deep over all. The inner and outer faces of the flanges slope together to a sharp point, making a flange of wedge section. The New York Central Railway uses a three-flanged Servis plate on the middle tie of its three-tie rail joints. The plate is 6 by 9¾ inches, and thirteen-sixteenths inch deep over all.

Shoulder tie plate—This is a flat-bottomed plate 5½ by 9 inches, one-fourth inch thick, with a shoulder or lug stamped upon the upper side, to take the lateral thrust of the rail. The inside spike hole is a slot 1¼ inches long, slightly diagonal to the rail, to allow for slight variations in the width of the base. A later form of this tie plate is made with an outer rib instead of the lug.

Southern Pacific Railway tie plate.—The redwood ties used on the Pacific Coast lines are very durable but soft, and to avoid the cutting of the wood a wrought iron tie plate has been designed and is manufactured at the company's shops. The plate is 9 inches wide and 7½ inches long, three-eighths to seven-sixteenths of an inch thick under the rail, and weighs 6⅓ pounds. There are four round holes for the screw spikes, and a rib on the upper side takes the thrust of the rail flange. There is no rib or flange on the bottom, as such flanges are found to occasionally split the ties, although they are an advantage on harder wood. Screw spikes are being tried, as with ordinary spikes in this soft wood it has been found difficult to hold the rail firmly to the tie, and the play between rail and tie contributes very largely to the cutting and wearing of the wood.

Miscellaneous tie plates.—Mr. C. C. Wrenshall proposed a flat plate with bolted clamp fastenings, the bolts passing through the ties. Mr.

M. W. Thompson, of the Pennsylvania Railroad, in 1889 designed a heavy flat-bottomed plate, with a groove for the rail base, the rail being secured by three screw spikes and clamps. The plate was 7 by 9 inches, and three-eighths of an inch thick under the rail. The Columbian tie plate has a rib on top and two ribs underneath, each of the latter extending only half way across the plate, so as to avoid severing all the fibers between the two flanges. The Wolhaupter tie has a top rib and bottom ribs in either or both directions. The Servis, Goldie, and Churchward plates are those most extensively used thus far.

FOREIGN TIE PLATES. (*See* Pl. 2 and 3.)

Tie plates of various forms have been extensively used in Europe and other countries to prevent the cutting of ties by T rails. They are generally made heavier than those used in this country. As a rule, the plates are flat bottomed, some few having teeth, and others a rib fitting into a notch cut across the tie. The cutting of the ties in this way, or to let the tie plates in flush with the top of the tie, appears to be a bad practice. The difficulties arising from the looseness of flat plates is overcome in part by secure fastenings in the way of screw spikes, bolts, etc. Compression of the wood under the plate makes it necessary at first to occasionally tighten up the fastenings, but the compression is slight and does not continue, so that when once firmly settled the fastenings require but little attention.

Belgian state railways tie plate.—With the 76-pound and 104-pound Goliath rails on creosoted oak ties, each tie is protected by flat-bottomed tie plates, with the exception of the joint ties for the 104-pound rails, on which the heavy flanges of the angle bars take a bearing, screw spikes passing through these flanges. The tie plates under these heavy rails are of grooved section, and have three holes for screw spikes. The plates are 9.6 by 5.2 inches, and 0.56 inch thick under the rail. The spikes are 6.8 inches long over all. The 76-pound rails rest on flat tie plates, 0.5 inch thick. Those at the joints are 6.8 by 7.4 inches, with 4 square holes for spikes, and those on intermediate ties are 4 by 8 inches, with 2 spike holes. (*See* Belgium, Part I.)

French railway tie plates.—Many of the railways using T rails employ also grooved tie plates, with screw spikes bearing directly on the rail flange, as in the Belgian plates, while at joints the flanges of one or both of the angle bars rest upon the tie plate, and the screw spikes pass through both angle bar and plate. The plates are flat bottomed, about 8 inches wide and one-half inch thick under the rail; and to prevent lateral shifting they are let into the tie about three-fourths of an inch; but this does not seem to be a good arrangement, on account of the expense and the liability to rot in the corners and seats.

Hohenegger tie plates.—The Northwestern Railway of Austria uses largely on its wooden cross-ties a large tie plate designed by Mr. Hohenegger. The plate is 13.92 by 5.6 inches, for a rail only 4.16 inches wide on the bottom. The inner edge of the plate has a rectangular rib fitting into a groove cut across the tie. There are four round spike holes 0.84 inch diameter, and the rail is held by two bolted clamps, the bolts having countersink heads fitting into recesses in the plate. The clamps are reversible and the gauge is adjusted by the inclined face of the outer edge of the clamp bearing against an inclined face on the ribs of the plate. The thickness of the plate is from 0.44 to 0.8 inch.

Indian state railways tie plate.—The railway department has adopted a flat-bottomed tie plate for use under the standard 75-pound T rails, and the plate is in general similar to that of the Southern Pacific Railway (*see* Pl. 3). It is 7½ by 6½ inches, seven-sixteenths inch thick under the rail, and has a rib on the upper side. The plate has 4 spike holes, three-fourths inch square, and the rail seat is inclined so as to give the rail an inward cant, in accordance with foreign railway practice, to fit the curving of the wheel treads.

Post's tie plate.—The tie plate designed by Mr. J. W. Post, of the Netherlands state railways (the inventor of the well-known Post steel ties), is of the heavy type usually adopted in European railway practice, and is used with clamps and screw spikes for rail fastenings. It is made with the bottom flat and also with sharp teeth on the bottom, the teeth being about three-sixteenths inch deep, but Mr. Post states that if the tie has a knot or hard place at the seat for the plate, the flat-bottomed plate is the better, as the toothed plate sometimes gives an irregular gauge under such circumstances. The steel tie plate of this type now used on the Netherlands state railways is flat bottomed (except that the maker's mark is in raised letters on the bottom), but is otherwise similar to the form illustrated. It is 8.56 inches wide and 8 inches long, 0.52 to 0.74 inch thick at the rail seat, which is 4.32 inches wide, inclined 1 in 20. The outer edge of the rail butts against the edge of the rail seat, and is held by a screw spike whose head bears directly upon the rail and the side of the tie plate. The inner flange is held by a clamp and a similar spike. The plate has 3 spike holes 0.96 to 1 inch diameter along each side. The spikes are 7.5 inches long over all, 5.56 inches long under the head, 0.57 inch diameter in the shank, and 0.89 inch diameter over the threads, which have a pitch of 0.48 inch. The spike head is 2 inches in diameter, with a tapering projection, 0.84 to 0.92 inch square, for the socket of the track wrench.

Prussian state railways tie plate.—The standard track consists of 82.65-pound T rails resting on flat-bottomed steel tie plates 7½ by 6½ inches and one-half to eleven-sixteenths inch thick under the rail. Each plate weighs 8.82 pounds. The top surface is grooved to fit the rail flange, and the rail seat is inclined, in the same way as that of the Indian state railways plate. Three screw spikes are used.

Sandberg's tie plates.—Mr. C. P. Sandberg, the well-known European rail expert, has devised different forms of steel tie plates, but they are all of the flat-bottomed type. His first plate had lugs stamped up to engage the rail flange, the rail being secured by a taper steel key driven between the rail flange and lug of plate, as in the Kendel steel tie (India and Mexico, Part I). The plate was secured to the tie by 3 bolts through the tie, with fang washers for the heads. These plates have not been adoped to any great extent, partly because of the expense, and partly because the Sandberg rails are used principally in the cold countries of northern Europe, where the track heaves in winter and considerable shimming is necessary. They were laid for 2 miles, with 100-pound T rails, on the Furness Railway, England, and gave no more trouble than the ponderous arrangement of double-headed rails and chairs in the adjacent track. Another form of plate had 2 lugs for the rails and 2 spikes to hold the rails; while 2 extra spike holes were provided in case the plate needed to be more securely fastened to the tie. In the Belgian state railways the Sandberg "Goliath" rail is laid on ground tie plates and secured by screw spikes with wide flat heads, which bear on the rail flange and edge of plate. In view of the difficulty of introducing these plates, Mr. Sandberg has modified his rail sections so as to give an unusually wide base of rail, but it is doubtful whether good rails of such a design can be successfully made.

Seidl tie plate—This German invention is a flat, narrow bar or plate nearly as long as the tie and laid upon it. The ends are inclined to form tie plates and have holes to receive the smaller lower part of rail clamps of ⊤⊓ shape, through which pass screw spikes.

APPENDIX 1.

PRESERVATION OF WOODEN TIES.

(1) WOOD PRESERVATION.[1]

By HENRY FLAD, C. E., *St. Louis, Mo.*

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Wood is made up of small fibers, the various forms of which constitute its cell structure. Air occupies the cells not filled with sap.

The woody fiber in all kinds of wood is composed of the same elements, and in nearly the same proportions. It consists of 52.4 parts of carbon, 5.7 parts of hydrogen, and 41.9 parts of oxygen.

Differences in the strength of timber are due to differences in structure, or in the form and disposition of the fibers. The specific gravity of the fiber is about 1.5.

The sap consists mainly of water and of the so-called extractive substances, such as vegetable glue, gum, gallic acid, coloring matter, sugar, albumen, etc. Besides these substances, which are found in greater or smaller quantities in almost every kind of sap, that of some kinds of wood contains special ingredients. Oak contains tannin; the coniferous woods contain resin, essential oils, etc.

The quantity of sap contained in wood varies considerably in different kinds and at different seasons of the year. Freshly cut wood contains from 18 per cent of sap (in hornbeam) to 52 per cent (in black poplar). The variation of sap at different seasons is illustrated by the observation that ash cut in January was found to contain 29 per cent of sap and 39 per cent when cut in April.

When wood is thoroughly air-dried it still contains from 16 to 20 per cent of water, and when air-dried wood is exposed for a time to a temperature of 277° F., the quantity of water is reduced to one-fourth or one-fifth of what was left in the air-dried wood.

NOTE.—The following table exhibits the weight of 1 cubic foot each of different kinds of air-dried wood and the space in a cubic foot, or 1,728 cubic inches, of air-dried wood occupied, respectively, by fiber, sap, and air, assuming the specific gravity of fiber at 1.5:

	Weights of 1 cubic foot.				Space occupied by fiber, sap, and air.		
	Pounds.	Per cent of water.	Weight of water.	Weight of fiber.	Fiber.	Sap.	Air.
					Cub. in.	*Cub. in.*	*Cub. in.*
White oak	53.3	16	8.5	44.8	830	161	662
Yellow pine	34.4	17	5.8	28.6	530	161	1,037
White pine	26.1	17	4.4	21.6	400	125	1,203
White beech	45.2	18.5	8.4	36.8	681	233	814
White elm	36.2	18.5	6.7	29.5	546	186	996
Sweet gum	39.6	19	7.6	32.0	592	211	925
Yellow poplar	33.0	19.5	6.4	26.6	493	177	1,058
Sycamore	33.4	20	6.7	26.7	494	186	1,054

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[1] In this paper notes signed with the initials H. C. are to be credited to Mr. Howard Constable, C. E., of New York City, who had kindly prepared a separate paper on the same subject, but to avoid unnecessary repetitions his paper has been divided and used as footnotes along with the report.

The weight of water per cubic foot, as given in the third column of the above table, and the weight of fiber per cubic foot of lumber, in the fourth column, were calculated from the observed percentage of water contained in the wood, as given in the second column.

In air-dried wood from one-third to nearly two-thirds of the volume is occupied by air, which might be replaced with some liquid if the air were removed, or partly replaced if the air were compressed. (Knapp's Technology.)

DECAY OF WOOD.

The woody fiber by itself does not seem liable to decay, but the sap contained in it under favorable conditions undergoes fermentation, and fungi attack and destroy the fiber.

Fermentation, however, can not take place except in the presence of air, moisture, and of a temperature above the freezing point (32°) and below 150° F. If any one of these conditions is lacking decay is impossible.

But if wood is to be exposed to conditions favorable to decay, special precautions and means can and should be adopted to prolong its usefulness. The sap being the prime cause of decay, it is plain that timber should be cut at a season when it contains the least quantity of it and the least amount of organic matter, viz, during winter.

It is stated on good authority that wood of proper character and age cut during January and then air-dried resisted decay for fifteen and sixteen years, whereas timber of the same kind cut at different age and season lasted only four years.[1]

METHODS OF TREATMENT.

The methods which are used, either simply or in combination with each other, in the preservation of wood, are—

(1) Steeping in water or in antiseptic solutions.

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[1] Experience has shown that wood cut in August, if properly seasoned, will last as long as that cut in winter. The manner of after-treatment will decide mostly for or against the practice of summer cutting. If no precautions are taken as to proper seasoning the winter cutting is decidedly preferable.—B. E. F.

It is also evident that the total or partial removal of the sap from wood will retard its decay. But even if all sap were removed decay would naturally set in if the entrance into the cells of air and water containing spores is permitted, or if no means are adopted to prevent their growth when introduced.

To prevent air and water from entering the wood its cells may be filled with some substance not liable to decay. To prevent organic life from springing up in the wood cells antiseptics are introduced into them in the form of solutions which act as poisons on all kinds of spores and bacteria.

NOTE.—There is no doubt whatever that wood can be preserved successfully and to commercial advantage to a much greater extent than is generally believed. To experts in this field little need be said; they are aware of its extent, what has been accomplished, and the possible advantages. They know that the preservation of wood has been carried on in England and in several countries of Europe for a great many years on a very extensive scale and with the most satisfactory results, several processes being in use whose efficiency has been thoroughly established. Experience in this country has not been satisfactory, owing to a want of appreciation of certain conditions very different from those found abroad. Among these it is noticeable that we have usually green timber to treat instead of seasoned wood, and that in some localities timber is yet too plentiful and consequently cheap to admit a preserving process being employed to commercial advantage. In some cases, again, experiments have not been satisfactory owing to the great distances to which wood had to be transported for treatment and then to be sent back.—H. C.

(2) Forcing a current of water or of antiseptic solution longitudinally through the ducts of the wood, either by pressure or by suction—the Boucherie process.

(3) Steaming in closed vessels.

(4) Removing air and vapors from the cells by creating a vacuum around the wood in a closed vessel, and then injecting the antiseptic solution into the wood by applying pressure to the solution.

(1) *Steeping.*—When wood is steeped in running water its sap is diluted and gradually displaced. This is the cause of the greater durability of rafted lumber as compared with that which has not been submerged in water.

But the process is necessarily slow, and if the water in which the wood is submerged contains sediment the process is impeded.

Steeping is also used for impregnating wood with antiseptic solutions. To allow such solutions to enter the wood the latter should first be freed from water, either by air drying or by exposing it to heated air in kilns. Steeping requires much time (from one to two or three weeks) and can never effect a thorough impregnation of the wood. The structure of wood is such that, while it offers but slight resistance to the flow of liquids through its longitudinal ducts, it is very difficult, even under great pressure, to force any liquid from the surface to its center at right angles to the direction of the fibers. But the entrance of any preserving liquid through the ducts and other cells is resisted by the sap remaining in the wood and by the air which fills the cells not occupied by sap, so that steeping, as generally carried out, causes the antiseptics to penetrate but a short distance from the surface of the wood.

It is evident, therefore, that wood which is to be preserved by this method of impregnation should be fully framed to the exact form in which it is to be used before it is treated.

Steeping may sometimes be useful as a process preparatory to others.

(2) *The Boucherie process.*—About forty-five years ago Boucherie, a French chemist, conceived the idea of impregnating wood with a preserving fluid by introducing it into a living tree through a groove cut around its surface near the ground, from which it was to arise, together with the sap, through the cells of the wood.

But it was soon found impracticable, and in 1841 Boucherie patented a process for preserving wood by forcing a solution of sulphate of copper through the cells of the wood under hydrostatic pressure applied at one end of freshly cut and unbarked logs, so as to remove the sap and replace it by the solution of copper. Since then impregnation with sulphate of copper has been generally known as the "Boucherie process," although this term is more properly applied to the method of impregnation invented by him, which may also be used in connection with other preservatives as well as with copper.

To secure the ready percolation of the fluid through the cells of the wood it is necessary that the sap of the wood to which the process is to be applied should possess the greatest possible degree of fluidity. This it has during the first months of the year. Timber cut during the autumn may also be used, although the sap at that season is more viscous and less readily removed. During the spring and summer the sap contains so much gummy extractive matter that it is not fit for treatment by this process. The timber is treated in the form of round logs, with the bark left on. The treatment should be applied as soon as possible after the timber has been cut. When exposed to the action of the atmosphere, even for a short time, the sap will solidify and greatly retard the process. It is customary, therefore, to cut the logs of somewhat greater length than that ultimately required, and to saw off a few inches from the ends just before subjecting the logs to the process.

Logs which are placed in clear water immediately after they are cut will remain for some time in proper condition for treatment. If the logs are intended for railway ties they may be cut of suitable length to make either one or two ties, and the mode of introducing the solution varies accordingly. Logs cut for single-length treatment are placed (with a slight inclination) in a row on skids, and fastened to the latter by clamps. Along each row of logs runs a pipe, connected with an elevated tank which contains the antiseptic solution. Around the periphery of the end of the log nearest the pipe a greased rope is then laid and pressed against it by a plank which is drawn tight against the log by clamps.

Thus a cylindrical chamber is formed into which the solution is admitted by a rubber hose connecting the pipe with the chamber. The admission of the solution may be stopped by clamping the hose. When the solution is first admitted the air contained in the chamber is allowed to escape through a small opening near the top of the chamber, and then the solution enters the open ducts in the wood, pushing the sap before it, and finally escapes at the opposite end, where the mixture of sap and solution drips into a trough placed along and under the ends of the logs.

When logs cut to double lengths are to be treated, after having been placed on the skids they are sawed very nearly but not quite through in the middle. Wedges are then used to raise them at the middle so as to open the saw-cut wide enough to admit the introduction of a greased rope, which is placed around the circumference of the cut. The wedges are then taken out to allow the cut to close up, and thus to compress the rope and to form a close chamber. The solution enters this chamber through a short tube driven into a hole which is bored slantingly a few inches from the cut through the end of one of the logs. Rubber hose leads from the hole in the log to the pipe. The air is allowed to escape from the chamber by using a pin to make a small hole at the top of the greased rope, which is then plugged. Of course two troughs have to be placed along and under the outside ends of the logs, where the liquid leaves the logs. The troughs carry the escaping solution to a tank, where it is restored to its normal strength. But as the solution in passing through the logs is mixed with the sap it will, even if the scum is removed with ladles and the fluid filtered through woolen cloth, soon become impregnated with foreign substances to such an extent that it can not be safely used any longer.

This may be remedied to some extent by filtration. At the foot of the trestle carrying the tanks are placed as many filtering tanks as there are tanks on the trestle. The filtering tanks are closed by covers, which can be readily raised when the filtering material is to be introduced, and then closed and firmly anchored to the tank.

The fluid delivered by the troughs is pumped into one of the upper tanks, from which it is conducted by a pipe to the bottom of a filtering tank, whence, under a head due to the elevation of the tank, it passes upward through the filtering material and through a pipe starting from the cover of the filtering tank to a pump which raises it again to a second tank on top of the trestle. There the solution is brought to the normal strength and then starts on a new round. Such filters have to be cleaned daily.

It would appear that a cheaper, if not more expeditious, method of preventing the adulteration of the solution could be found by passing only clear water through the logs at the beginning of the treatment, continuing this process until the sap has been removed, and only then introducing the antiseptic solution. The water, after passing through the logs, would be allowed of course to run to waste.

The removal of the sap might, perhaps, be expedited and made more complete by using a weak solution of borax, instead of pure water, at the beginning of the operation.

In France, where the Boucherie process was for many years used exclusively for impregnating wood with sulphate of copper, the rule was to continue the treatment until every portion of the end from which the solution escaped showed the proper reaction when tested with ferrocyanide of potassium. It was also a rule not to stop the operation until the solution escaping from the end, when tested by chemicals, showed a strength of two-thirds of the original solution, the wood retaining almost all the sulphate of copper at the beginning of the treatment, and gradually less, so that the solution flowing from it showed a corresponding increase in strength. The time required for thoroughly impregnating wood by this process was found to vary with the state of the atmosphere, with the dimensions of the log, and with the quality of the timber. A humid and mild atmosphere was the most favorable, while dry and cold weather retarded the process. During freezing weather operations had to be suspended.

As to the influence of dimensions on the time required for treatment, it may be assumed that the time required is directly proportional to the diameter of the log and to the square of its length. It may also be assumed as being inversely proportional to the hydrostatic pressure applied.

Timber in which the annual rings do not differ much in width, such as beech and hemlock, is more readily impregnated than timber in which the heart is much more compact than the sapwood, as in oak. No attempt should be made to treat timber which is not perfectly sound throughout its whole section and length.

With fresh-cut beech logs intended for ties it took on an average about forty-eight hours to complete the impregnation. Logs of greater length and of other kinds required as much as one hundred hours for treatment. In cases where the impregnation was found not to be completed at the end of one hundred hours it was customary to reverse the position of the logs and to force the solution through in the opposite direction.

This process has been most extensively used in France, and to a smaller extent in Austria and Germany. In England it has never been applied, because nearly all timber used there is introduced from abroad. In the United States it has been used, so far as I am aware, in but few instances.

Yet its use insures, probably, a more thorough impregnation than any of the other methods employed at present. It does not injuriously affect the strength of the wood, and requires a comparatively small outlay for plant. It can be started almost anywhere within a short time. Its drawbacks are that it can be carried on only during a comparatively brief season; that it takes considerable time, although less than the steeping process, and that it can not be applied to square timber.

Considering that the large quantity of air which even fresh-cut wood contains must necessarily obstruct the passage of the solution through the log and prevent the fluid from reaching every portion of the wood; considering, moreover, that in pushing the solution through the ducts by pressure it was exposed to waste at every point where the ducts reached the surface, and that such leaks were difficult to stop, I concluded to make an experiment to see whether better results could not be attained by reversing the Boucherie process, and applying suction instead of pressure for passing the antiseptic solution through the logs. Instead of using an elevated tank, I employed two small closed vessels, in one of which a partial vacuum was kept up, while the other was being emptied of the sap and solution delivered into it by the pipe, which passed along the ends of the logs, and which was connected with the vacuum tanks, and by small rubber hose with the chambers formed at the head of each log. The caps in this case consisted of a thin, flexible metal ring, with sharpened edges. One edge was driven in near the circumference of the cut, and when firmly fixed, the disk, 2 to 4 inches thick, which had been cut from the end of the log to prepare it for treatment, was driven into the other edge of the metal ring. This wooden bottom of the chamber was made air-tight by smearing clay or tallow over the outside face.

A small knob fixed to the circumference of the metal ring contained a short tube, to which the rubber hose was attached by merely slipping it over the end of the tube. A cock in the short tube served to permit or to stop the exhaustion of the air from the chamber at the end of the log. The log was always placed so that the suction end was at a higher elevation than the end at which the solution entered the log. The introduction of the solution was managed in two different ways. In one, a chamber, identical with that at the suction end, was formed at the other end of the log, and the solution introduced into this chamber from a trough running along and 4 feet above the lower ends of the logs. This arrangement gave pressure at one end and suction at the other, thus greatly expediting the operation. Cuts of the fibers at the surface of the log, such as would be produced by chopping off branches, through which the air might be sucked, were readily detected and could be quickly stopped by rubbing clay or tallow into them. When the cock in the pipe connecting the suction chamber with the main pipe was opened, the first result was that the air contained in the cells of the wood was drawn into the suction chamber, and thence into the main suction pipe and vacuum tank, thus forming a vacuum inside the ducts of the log, which caused the sap and the solution from the lower chamber to follow in a solid column and gradually to fill the wood with the antiseptic solution.

Another method was to place the logs in a triangular tank in such a manner that the lower end of the log, to which in this case no chamber or cap was fixed, would be completely submerged in the solution. When the cock controlling the connecting pipe was opened the air and sap contained in the log were exhausted from it and the cells gradually filled with the solution. In some cases the tank was first filled with water for the purpose of washing out the sap before the antiseptic solution was used.

The antiseptic generally used was sulphate of copper, because its presence or absence can be determined constantly by the application of a solution of ferrocyanide of potassium, and the experiments were instituted mainly for the purpose of ascertaining how long a time was required to thoroughly impregnate the logs.

With sound logs of 12 to 20 inches diameter, cut into lengths of 8 feet, it was found that the wood was thoroughly impregnated in from five to eight hours. This was ascertained by sawing the log in two after it had been treated and testing the whole surface of the cut with the reagent. But when the logs were not perfectly sound the impregnation was imperfect.

A small experimental station was afterwards erected near Charleston, in southeast Missouri, where it was intended to test the commercial value of the process, and a number of large logs, mostly sweet gum, were impregnated. But as this kind of timber contains a great deal of sapwood, and as most of the large logs show incipient decay at the center, the results were not nearly as favorable as those which had been attained by the previous experiments with logs cut from other kinds of timber and smaller diameter, sound and of uniform texture.

The experiments were interrupted by the illness of my son, who had charge of the work, and a season of high water, which kept the ground at the works and for miles around, submerged for several months, induced me to discontinue the experiment altogether.

But I believe that under proper condition the method just described will cause a more thorough impregnation of wood than can be secured by any other, without the necessity of an expensive plant and without injury to the strength of the timber.

I believe, also, that it might be used to good advantage in works where now steeping alone is relied upon, with a view of expediting the process and of impregnating the timber not only near the surface, but also deeper. The timber, when submerged in the antiseptic solution, might be fitted at one end with a metal cap, as heretofore described, and the fluid sucked through the timber by exhausting the air and liquid from the cap. Square timber, even if of large dimensions, might thus be treated, the metal ring in that case being made of the same form as the section of the timber, and in dimension one-half or 1 inch smaller than that section. To effect complete saturation the fibers of the wood would have to be straight and parallel to the sides of the timber, but by applying the process to both ends a thorough impregnation of the inner portion of the timber would, in most cases, be obtained, while the parts near the surface would be impregnated by steeping.

In describing at such length two processes which are not used I have been influenced by the consideration that, while neither of them can ever find general application, there are undoubtedly locations and circumstances in which preservation by a process requiring but slight outlay for plant is the only one feasible; and, so far as I am aware, a full description of these processes has never been furnished in any of the American publications treating on the subject of the preservation of timber.

(3) *Steaming.*—When fresh timber is placed in a closed vessel and steam admitted into the latter, the first effect will be to expel the air, a tap provided for that purpose being left open. When the air has been driven out this tap is closed, and, more hot steam being admitted, the temperature of the timber and of the sap contained therein rises gradually. When the temperature in any part of the timber rises to 167° F., the albumen which is generally considered the ingredient in the sap most favorable to decay becomes solid. The air expands and a portion of it leaves the cells. The water contained in the cells is gradually transformed into steam, and the water of condensation, together with a great portion of the extractive ingredients of the sap, is driven from the wood and collects at the bottom of the boiler, whence it is from time to time drawn off by a tap. The steam admitted should not have a pressure greater than about 20 pounds (corresponding to a temperature of about 260° F.).[1]

To coagulate all the albumen it is, of course, necessary that every part of the timber should be heated; but heat enters rather gradually and slowly from the surface to the interior. Experiments made by introducing Rose's metal into holes bored into the timber from the surface which afterwards were plugged, showed that after three hours' steaming, the heat required for coagulating albumen had penetrated only to a depth of 3 to 4 inches. It is evident, therefore, that if all the albumen in the wood is to be coagulated the time during which the timber is steamed must be regulated according to its dimensions.

With timbers of considerable length and of large cross section, it may be necessary to continue the process for six and eight hours or more. But such long-continued steaming will soften the fibers, weaken their coherence, and reduce the strength of the timber. Experiments made in Hanover show that the ultimate strength of burnettized wood was reduced by one-fourth to one-tenth, and its elastic limit by one-seventh. Some part of this reduction was probably due to the action of the antiseptic used—chloride of zinc; but there can be little doubt that it was also partly due to the steaming.

Steaming has some other unfavorable features. A portion of the albumen, although coagulated, remains behind and partially stops up the cells, hinders the free circulation of steam and sap, and ultimately the entrance of the antiseptic solution. The process, moreover, does not fully remove the viscid ingredients of the sap, which, next to albumen, are most favorable to decay, while it deprives the wood completely of the essential oils and of tannic acid, which are, to some, extent preventives of decay; and, finally, unless the process be followed by some process of drying, as by superheated steam, and by application of the vacuum process (which will be described hereafter), it leaves a considerable quantity of water of condensation in the wood, making it incapable of impregnation with at least one of the best antiseptic substances (heavy oil of tar), and hindering complete impregnation with other preservatives.

That a considerable quantity of water remains in the wood after simple steaming was proved by experiment, when it was found that of the water introduced into the vessel in the form of steam only two-fifths to four-fifths were removed from the boiler as water of condensation, so that from one-fifth to three-fifths remained in the wood.

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[1] It would probably be even better to restrict the temperature of the steam to 240°, or 10 pounds pressure, to prevent injurious effects to the strength of the wood where bridge timbers are to be preserved, although the process would take more time.

(4) *The vacuum process.*—In 1838 Burnett patented a method of preparing timber for receiving the preserving fluid, by placing the timber in a closed vessel and then using an air pump for removing the air and vapor from the cells of the wood. He next filled the vessel with the antiseptic fluid, and applied a pressure as high as 150 pounds per square inch, by compressing the air above the solution. From the use of compressed air his was named the pneumatic process, and it retained that name even after the use of compressed air had been abandoned, and the pressure was directly produced by pumps.

This process, preceded by steaming and vacuum, is the one now almost universally used.

The timber to be treated is placed on cars, which are then pushed into a boiler, 6 to 8 feet in diameter, and from 60 to 110 feet long, of sufficient strength to safely bear an internal pressure of 150 pounds, and a collapsing pressure of 12 or 15 pounds. The boiler is then closed, and steam admitted under a pressure of 10 or 20 pounds. Steaming is kept up, as heretofore stated, for from three to eight hours, and is followed by exhausting the air and vapor still contained in the wood for from one to three hours, until the vacuum becomes constant on the stoppage of the pumps. The antiseptic solution is then admitted to the boiler, and when the latter is filled with the liquid, force pumps are employed to force the solution into the cells of the wood under a pressure of 100 to 150 pounds. The pressure is kept up until, on stoppage of the pumps, it remains nearly constant; say from three to sixty hours, according to quality, kind, and dimensions of the timber.

The cars with the timber on them are then removed from the boiler and a new charge introduced.

NOTE.—Many seem to be under the impression that the effect of the vacuum in drawing out the sap and air is unlimited, and the same as regards the pressure in forcing the preservative into and through the wood. We have no doubt that the vacuum and pressure are of great benefit, but to what extent the complete impregnation of the wood is affected by the amount of air that may be in the wood cells remains to be settled by further investigation, and more precise information would be useful. In green and rafted timber the sap is in a more or less liquid form, and the log may thus be so full of moisture as to contain a minimum amount of air, and steaming can be of benefit only by making the sap more fluid, the moisture of the steam being of no advantage. The heat also expands what air there is in the wood and thus drives out some of the moisture. With such timber it probably would be better to apply dry heat rather than by direct steaming, and thus add heat without extra moisture, for if we get a stick of timber thoroughly water soaked, the wood cells are full of water and there is no place into which to force the preserving fluid.—H. C.

ANTISEPTICS USED IN THE PRESERVATION OF WOOD.

Out of the great number of substances which, during the last sixty years, have been proposed for preserving wood from decay, or rather for prolonging the period of its usefulness, only four have stood the test applied, and are now employed for that purpose.

1st. Heavy oil of tar (creosote oil, dead oil).
2d. Bichloride of mercury (corrosive sublimate).
3d. Chloride of zinc.
4th. Sulphate of copper.

In addition to these some substances are employed for preventing the gradual removal of these antiseptics from the wood by exposure to atmospheric influences, such as chloride of tannin, glue, tannin, and sulphate of lime.

(1) *Heavy oil of tar.*—The heavy oil of tar is the product of the distillation of coal tar between the temperatures of 480° and 760° F.

It generally contains from 5 per cent to 10 per cent of cresylic acid, the remainder consisting of heavy oil and naphthaline in varying proportions. An analysis of the oil, as imported from England and used at the works at Slidell, La., gave 9.75 per cent of carbolic and cresylic acid, 12.50 per cent of naphthaline, and 77.75 per cent of heavy oil.

At 65° F. it weighs about 9 pounds per gallon, and boils at a temperature of 265°. It has great antiseptic qualities, and being insoluble in water, has the advantage over all other substances used for the preservation of wood, in that, when applied in proper manner, it forms a coating to the woody fiber, which prevents water and air from coming in contact with it. Being insoluble in water, it can not be removed by immersion in water. It is, moreover, the only substance which will permanently protect timber against destruction by the *Teredo navalis* and other parasites.

Impregnation with heavy oil of tar, or creosoting, as it is sometimes called (from the fact that creosote was considered the active preservative principle), was patented in England by Bethell, in 1838.

The method of treatment proposed by him was to remove the air from the wood, to heat the oil to about 120° F., and to inject it into the wood by pressure. To admit of proper impregnation, the wood should be freed from water so far as possible. In England, air-dried wood is readily procured, which, being placed in a closed vessel in which a vacuum has been established, can be easily prepared for the reception of the oil. In this country, where the wood generally has to be impregnated soon after it has been cut, and where steaming has to be resorted to for driving out the sap, special means must be adopted to remove the water of condensation from the wood, after steaming, if the treatment is to be successful.

As to the quantity of oil required to preserve the wood, it may be said that the useful effect of the impregnation is proportional to the quantity of oil injected into a given volume of wood. If all the void spaces in the wood could be filled, it would take from one-half to two-thirds of a cubic foot, or from 35 pounds to 50 pounds of the oil for each cubic foot of timber. The practical limit would probably vary from 25 to 50 pounds per cubic foot, according to the kind of timber used.

But impregnation to such an extent would be altogether too expensive, and the quantity is therefore limited to what has proved by experience to be adequate for preservation under the conditions in which the wood is to be used. From 5 to 7 pounds per cubic foot is at present considered sufficient for railroad ties; about 10 pounds per cubic foot for bridge timbers; and for protecting piles used in marine structures, from 18 to 20 pounds per cubic foot are considered necessary according to the experience of American and French engineers, while English engineers consider 10 pounds per cubic foot sufficient protection for timber and piles in marine works.

The value of creosoting as a preservative against decay is shown by long experience. In England it is almost universally used for preserving railroad ties. Creosoted ties have been found perfectly sound after they had been in the ground for twenty-two years. In this country, creosoting was first applied in 1865 by Hinckley, on the Old Colony Railroad, for the preservation of piles; but the treatment was very imperfect, as the oil did not penetrate to a depth of more than one-quarter to one-half an inch below the surface. The piles were also trimmed and cut after treatment, thereby exposing untreated surfaces.

Yet in 1878, when these piles were examined, 200 of them were still found standing, although not in a sound condition. Some railroad ties (hemlock), which had been creosoted and placed in the track at the same time, were found to be perfectly sound.

Creosoted cypress ties, which had been laid in the track of the Central Railroad of New Jersey in 1876, on an examination made in 1883 by L. L. Buck, were reported to be sound, not much worn, and in all probability good for ten or twelve years' longer service.

In 1885, Mr. J. W. Putnam examined creosoted piles and bridge timbers, which had been in use on the line of the New Orleans and Mobile Railroad for nine years, and found them all sound; the piles had successfully resisted the attacks of the *Teredo.*

Some failures are reported in this country, but in every instance they can be shown to have resulted from imperfect treatment.

Creosoting works are established at Boston, New York, Pascagonla, Miss., Slidell, La., and Bayou Bonfauca, on the New Orleans and Northeastern Railroad.

Creosoting is undoubtedly the most effective means of preserving wood, and the only obstacle to its universal introduction consists in its being more expensive than any of the other systems of preservation.

(2) *Bichloride of mercury.*—The use of bichloride of mercury (corrosive sublimate) for the preservation of wood was patented and introduced in England by John Howard Kyan in 1833, and was soon very extensively applied. It coagulates albumen, and is the strongest antiseptic among metal salts; it is also very poisonous. Its solution attacks iron, consequently tanks, pumps, tools, pipes, etc., for holding it must consist of wood or india rubber, or must be coated with coal tar. It is soluble in water, and by using hot water a solution can be obtained of 1 part of bichloride of mercury and 6 parts of water. When it is to be used for the impregnation of timber the concentrated solution is diluted with the addition of water. The strength of the solutions used in impregnation has differed greatly. On the Boston railroads, where this antiseptic has been largely used for the preservation of railroad ties and sleepers, the strength of the solution was 1 part of bichloride of mercury to 150 parts of water, and the quantity absorbed by 100 cubic feet of dry pine wood, in the form of ties, was found to be 6.6 pounds; by 100 cubic feet of oak, 5.5 pounds; and 5 pounds by 100 feet of pine moderately dry, containing a large amount of resin.

The average duration of ties has been found to be as follows: Oak, not impregnated, lasted on the average fourteen years. Oak, creosoted, lasted eighteen years. Beech, creosoted, lasted eight to ten years. Spruce, creosoted, lasted twelve years.—B. E. F.

On the Eastern railroads the strength of the solution at first was 1 in 240 parts, and at present a solution of 1 in 99 is used. The timber is said to absorb about 2.6 pounds per cubic foot, while Mr. J. B. Francis states that in the Lowell works the wood is found to absorb about 6 pounds of sublimate per 100 cubic feet. In England solutions have sometimes been used containing 1 pound in 46, but without securing as good absorption as was obtained with weaker solutions, since only 2.2 pounds per 100 cubic feet were attained, it being probable that some of the sublimate was precipitated in the pores near the surface, stopping them sufficiently to partly prevent the entrance of the solution to the inside of the wood.

The impregnation of wood with corrosive sublimate has always been carried on by steeping. In Germany wooden tanks, from 20 to 35 feet long and from 4 to 5 feet in height, are used. The rule observed as to the length of time of immersion has been to leave ordinary railroad ties ten days in the tanks, lumber five days, bridge timbers fifteen days. In some works the rule is to steep pine ties for eight days, and oak ties for fourteen days.

At Lowell, Mass., where this process was introduced by James B. Francis, C. E., in 1848, and has been carried on (with an interruption of twelve years, 1850 to 1862) up to this time, the steeping is performed in wooden tanks 50 feet long, 7½ feet wide,

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NOTE.—In France all ties are impregnated, preferably with creosote, the cost per tie being as follows:

Kind of wood.	Cost of tie.	Cost of creosoting.	Total cost.
Oak	$1.00 to $1.18	20 to 40 cents.	$1.20 to $1.35
Beech	.67 to .77	40 to 45 cents.	1.07 to 1.20
Spruce	.35 to .40	15 to 20 cents.	.50 to .58

and 4 feet deep. The rule laid down by Mr. Francis for the duration of steeping is, that the timber should be kept immersed a length of time depending on its least thickness, one day being allowed for each inch in thickness, and one day in addition, whatever the thickness. This makes the time of immersion for a 6-inch timber seven days. At the works of the Eastern Railway at Portsmouth, Me., tanks 69 feet by 9½ feet wide, and 6 feet deep, built of granite laid in cement, are used. The inside of these tanks is coated with coal tar, applied hot. Ties 6 inches thick, according to H. Bissell, M. M. W., Eastern Railway, require one week; 12-inch timber, two weeks. The time of immersion is, therefore, nearly the same at all works. The difference in the quantity of sublimate absorbed (2.6 pounds per 100 cubic feet at Portsmouth, against 6 pounds per 100 cubic feet at Lowell and in Germany) could be due probably only to the fact that the timber treated at Portsmouth was not air dried.

Bichloride of mercury being a very active poison, great care in handling it is plainly indicated. In Baden it was considered necessary to take extra precaution against the poisoning of the workmen, and some prejudice was created against this mode of preservation on this account; but the experience in this country on this point is somewhat reassuring. Mr. Francis states that, in an experience in kyanizing, extending over more than thirty years, he has known no case where the men operating with it have been made ill. He says that men working over the tank in which the corrosive sublimate was being dissolved in hot water sometimes complained, but that he never knew any man to be seriously affected. He mentions, however, that in kyanized timber an efflorescence of the sublimate has sometimes been observed, which might be injurious to cattle, if licked off from timber to which they have access. This might be prevented to some extent if the precaution used in Germany was adopted—of washing with hot water the surface of the timber when treated, and before being exposed. Mr. Bissell corroborates the statements of Mr. Francis. He states that the man in charge of preparing the solution has, in a few instances, been nauseated for a short time by inhaling vapor arising from the solution; but that he believes this would have been prevented by a little more carefulness, and that the men handling the timber never suffered any injury, although frequently careless.

The testing of a solution of the sublimate, as to its strength, can readily and accurately be performed. A graduated test tube being filled with it, a solution of iodide of potassa is added, which precipitates the oxide of mercury as a red powder; which by the further addition of the solution of iodide of potassa is again dissolved, so as to leave a clear liquid. The change in color can be accurately observed, and the numbers on the graduated test tube can be so arranged that the man in charge can read off the weight of bichloride of mercury to be added to bring the solution to its proper strength.

There is ample testimony as to the efficiency of bichloride of mercury as a preservative of wood. The railroad ties of the Baden Railroad, impregnated with it, lasted from twenty to thirty years. Mr. Francis states that in 1850 he put up a fence of kyanized spruce lumber, which is still perfect, not a single piece having been removed during the thirty-five years, and only part of the wood which was under ground having decayed. The Pawtucket street bridge, built in 1849 of northern white pine (kyanized), did not require any repair until in 1882, a period of thirty-three years. Kyanized timbers were used in nine spans of the Burr truss bridge, at Georgetown, which stood from 1840 to 1862, and failed, not from the decay of its timbers, but from bad construction. The Blackstone River bridge, on the New York and New England Railroad, a Pratt truss built of kyanized timber in 1848, when taken down in 1876, after twenty-eight years' service, was found but slightly decayed. Two bridges on the Philadelphia and Reading Railroad, built in 1850 of kyanized timber, proved sound after twenty years.

The experience in this country as to kyanized ties is not as favorable as in Baden. This may be due to two causes. On the Baden Railway the ties and all other timbers are air dried during two or three weeks after impregnation, and before being laid, which precaution is probably not observed in this country; and the road bed in which the ties of the Baden Railway were laid consisted of a very dry gravel, which allowed all rain water to run off at once. But even on other German roads the success of kyanizing has been remarkable, and the failures which are recorded were due in many cases to imperfect impregnation.

Still, from the experiments of Mr. Francis, it seems to be certain that Kyanizing will give better results when the timber is exposed to air than when placed under ground. This results very likely from the sublimate being gradually dissolved and washed out. It might be prevented, probably, by first drying the treated timber and then giving it a coating of dead oil, on the ends at least.

(3) *Chloride of zinc.*—The use of chloride of zinc for the preservatio nof timber was patented by Burnett, in England, in the year 1838.

Chloride of zinc is prepared by dissolving metallic zinc in hydrochloric acid. In its most concentrated form it contains 32 per cent of zinc, but generally only 25 per cent. The specific gravity of a solution of this strength is about 1.6. It is sometimes made from zinc skimmings, and is then liable to contain free hydrochloric acid and chloride of iron. The first, like nearly all free acids, reduces the strength of the timber, while the second reduces the value of the solution as an antiseptic.

Chloride of zinc has the greatest affinity for wood fiber, and is hygroscopic, both being qualities which increase its value as a preservative. It is also a very strong antiseptic. Burnett at first recommended to use a solution of 1 part (by volume) of concentrated chloride of zinc to 59 parts (by volume) of water. In Germany stronger solutions were frequently used, 1 in 30, 1 in 24, and in one case even 1 in 14 parts. But it was found, as in the case of corrosive sublimate, that by using these stronger solutions the quantity of zinc absorbed by the wood was not proportionally increased, because such solutions would not so readily enter the cells, and that some portions of the timber received an excessive amount of the zinc chloride, while others received little or none. The presence of an excess of chloride of zinc, moreover, seems to injure the fiber, causing brittleness in the wood, and to prevent these consequences the strength of the solutions on German railways has been reduced to 1 in 50, or 1 in 60.

In this country solutions of 2 in 100 and 3 in 100 were used at first (Erie Railway Company). On the Philadelphia and Western Railroad the solution used contained 5 or 6 in 100; on the Philadelphia and Reading Railroad, 3¾ in 100; on the Havre de Grace Bridge, 1.12 in 100. At present the solutions generally used have a strength of 1.9 or 2 in 100. The strength of solutions is generally measured by the areometer; but the specific gravity of the solutions of zinc chloride changes so rapidly under changes of temperature that errors are unavoidable, unless proper corrections for temperature are made.

The weight of concentrated chloride of zinc, which was absorbed from a solution of a strength of 1 in 60, was found to be as follows on the railroads of Hanover, Germany:

One hundred cubic feet of oak absorb 22 pounds of concentrated chloride of zinc.

One hundred cubic feet of beech absorb 106 pounds of concentrated chloride of zinc.

One hundred cubic feet of spruce absorb 50 pounds of concentrated chloride of zinc.

At the works lately built at Las Vegas, N. Mex., with a solution containing 1.5 parts of concentrated chloride of zinc in 100 parts (by volume)—

Hewn ties absorb 33 per cent of solution (by volume), or 49 pounds of concentrated chloride of zinc in 100 cubic feet.

Sawed ties absorb 17 per cent of solution (by volume), or 24 pounds of concentrated chloride of zinc in 100 cubic feet.

Piles 40 feet long, 17 inches at the butt, 12 to 14 per cent, or 16 pounds of concentrated chloride of zinc in 100 cubic feet.

With a solution of a strength of 2 in 100, the absorption would be 75 pounds, 32 pounds, and 21 pounds per 100 cubic feet, respectively.

The efficiency of the chloride of zinc in preserving wood is well attested.

On roads in Hanover 169,000 ties (Burnettized oak) lasted, on an average, 19.6 years.

On the Rhine Emden Railroad 161,515 Burnettized fir ties lasted, on an average, 22.8 years; 81,000 beech ties, on the Hanover Railroad, lasted, on an average, 14.8 years; while, when left untreated, the average duration of oak ties in Germany is 14 to 16 years; of fir ties, 7 to 8 years, and of beech ties 2½ to 3 years.

As to the success of this mode of preservation on this country, the following facts may be mentioned: Of 2,000 Burnettized ties laid on the Chicago, Rock Island and Pacific Railroad in 1866 (pine, tamarack, and cedar, and the greatest part hemlock), when examined in 1881 by M. Alexander, roadmaster, 75 per cent were still found present in the track, and in such condition that they might do good service for two or three years longer.

L. L. Buck reports that in 1882 he examined a lot of Burnettized ties laid in 1866 and 1868, consisting of maple, beech, and hemlock, and found them, with few exceptions, in a good state of preservation, and more particularly the hemlock ties. He expresses the opinion that, although in the ground for sixteen years, they would probably last from seven to eight years longer.

R. M. Chaffee, president of the Union (horse) Railroad at Cambridge, Mass., states that of a lot of Burnettized spruce sleepers laid in that railroad, many were found in good condition after twenty-eight years' service.

A truss bridge of eight spans built for the Chicago, Rock Island and Pacific Railroad of Burnettized timber in 1860 was still in fair condition in 1882.

Where Burnettizing failed it was due to improper treatment. The fact alone that 22 out of 48 German railroad companies, who preserve their ties, use this antiseptic might be accepted as a proof of its efficiency as a preservative.

(4) *Sulphate of copper.*—Sulphate of copper (blue vitriol) had long been known as a strong antiseptic, but was first used for the preservation of wood by Boucherie in the year 1838. When used for this purpose it should be free from deleterious admixtures, among which the most common, and at the same time most injurious to wood, is sulphate of iron; for sulphate of iron is easily decomposed, and the free sulphuric acid resulting therefrom attacks and weakens the wood fiber.

The solution of sulphate of copper recommended by Boucherie consisted of 1 part (by weight) of sulphate of copper to 100 parts (by weight) of water.

The increase of timber in weight by impregnation with sulphate of copper was found by Boucherie, when his method of treatment was used, to be as follows per 100 cubic feet: Pine, 140 pounds; oak, 145 pounds; hemlock, 320 pounds; beech, 540 pounds.

But this increase in weight does not express the weight of dry sulphate of copper taken up by the wood, nor the weight of the diluted solution of sulphate of copper absorbed.[1] The weight of dry sulphate of copper absorbed by beech was found to be 32 pounds in 100 cubic feet of wood, and this is the weight of dry sulphate of copper which 100 cubic feet of this kind of wood is required to contain (1.1 pounds per tie of 3.5 cubic feet), under the specifications of the French engineers.

When the Boucherie process of impregnation is used, the weight of sulphate of copper required per cubic foot may be set down at 40 pounds per 100 cubic feet, to make allowance for loss in antiseptic resulting from his mode of treatment. Impregnation with solutions of sulphate of copper has been carried on by almost every known method of treatment, viz, by steeping, by the Boucherie process, and by vacuum and pressure.

One disadvantage in the use of this antiseptic consists in the fact that boilers, pipes, pumps, and tools used in carrying on the process must consist of copper, because contact with iron decomposes the sulphate of copper. This, of course, largely increases the cost of the necessary plant.

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[1] Boucherie found that in twenty-three hours 3,060 liters of solution entered into a beech log 15 meters long and averaging 0.9 meters in diameter, or about one-third of its total volume.

Another respect in which treatment with sulphate of copper is inferior to treatment with chloride of zinc, at least in preserving railroad ties, may be found in the fact that when ties treated with sulphate of copper are placed in the track the iron rails and spikes coming into contact with the sulphate of copper will decompose the latter, producing free sulphuric acid, which attacks the fiber and injures the strength of the timber. In some cases the endeavor has been made to prevent this by covering the ties, where they touched the rails, with coal tar, and by using galvanized spikes. Sulphate of copper is less hygroscopic than chloride of zinc, and ties treated with it are more liable to crack.

There is one point, however, in which it is superior to chloride of zinc, and which is of very great importance, when the treatment is to be effected under contract. While it is difficult to control the strength of a solution of chloride of zinc used in impregnation, or to find by chemical analysis the actual quantity of zinc contained in the timber after impregnation, both of these operations can be performed with great accuracy, and without much expenditure of time or money, when sulphate of copper is used. There can be less cheating, and therefore the success of the treatment as a means of preservation is more fully assured. To show the efficiency of the sulphate of copper in prolonging the life of wood, it may be stated that, according to German experiments, 60,000 fir ties which had been merely steeped in a solution of sulphate of copper lasted on an average thirteen and nine-tenth years; that 36,000 ties of the same kind of timber, which had been boiled in a solution of this same antiseptic, and laid on the Berlin, Potsdam and Magdeburg Railroad, lasted on an average fourteen years; and that 111,000 fir ties, impregnated with sulphate of copper under pressure, averaged sixteen years of usefulness; while unimpregnated fir ties used in the same railroads lasted only from seven to nine years. It may, therefore, safely be assumed that the durability of such ties would be doubled by proper treatment with sulphate of copper.

The use of sulphate of copper has been nearly abandoned in France, but is still carried on by some of the German railroads.

In this country it has been used only in connection with the Thilmany process, which will hereafter be described. One obstacle to its use may have been found in the fact that sulphate of copper formerly cost much more than chloride of zinc; but the price of copper has declined so much of late that the difference in cost has been greatly reduced.

NOTE.—The outfit for the Boucherie process is light and inexpensive, as well as that for Kyanizing, consisting of tanks in which to mix and store the preserving liquid and troughs to receive the sap; or, with the latter process, tanks in which to soak or steep the timber. The Burnettizing process and the Bethell process must prepare the wood by steaming, etc., and require iron cylinders, a steam boiler, and pumps. But the usual form can be modified, as Col. Flad has indicated, by using two or more smaller cylinders with boiler and pumps, all attached to trucks or arranged to be easily handled, and with all pipe connections so arranged as to be made or broken readily.

The advantages of a movable plant have received less attention and have been tested less than they deserve. The transportation of timber is, of course, a considerable item of expense. A plant of moderate size could be taken to the various sources of supply from which the timber comes or to the most economical distributing points, and thus the cost of transportation, in one direction at least, would often be saved.—H. C.

METHODS AND SUBSTANCES USED TO RETAIN ANTISEPTICS.

The heavy oil of tar, being insoluble in water, will not be removed from timber which has been impregnated with it, even if the timber is permanently submerged in water. But the metallic salts at present used in wood preservation, bichloride of mercury, chloride of zinc, and sulphate of copper, being injected into the wood in the form of aqueous solutions, are, of course, liable to be dissolved again by moisture and eventually to be removed when the the timber is exposed to the action of water. Experiments made by chemists seem to prove that a portion, at least, of the sulphate of copper and of chloride of zinc combines with the fiber of the wood and can not be removed again; but all that has not been fixed by such combination may, in the course of time, be removed from the wood when permanently immersed in water. Metallic salts should, therefore, not be used when wood is exposed to the constant action of water, and it would be desirable to adopt means for preventing even the gradual, but much slower, removal of the salts by rain and moist air, although the favorable results with wood which had not received such extra protection leaves some doubt as regards its economical value.

The methods which are now used for preventing the "washing out" of the metal salts are: (1) The Thilmany process; (*a*) with sulphate of copper; (*b*) with sulphate of zinc. (2) The Wellhouse process. (3) The zinc-gypsum process. (4) The zinc-creosote process.

1. *The Thilmany process.*—Thilmany, in 1869, took out a patent for a method of preservation by which the wood was first to be impregnated with sulphate of copper and then to be immersed in a bath of chloride of barium. An interchange of the constituents of these two salts, if brought together in the proper proportions, would leave the timber impregnated with chloride of copper and sulphate of barium, which latter, being insoluble in water and in all acids, was expected to fill up the pores of the wood so as to prevent the removal of the chloride of copper by water entering from the outside.

The process was first tried at Cleveland, Ohio, with blocks for wood pavement. As far as I am informed, the wood was treated with sulphate of copper by the Boucherie process and then immersed in a bath of chloride of barium. In 1881 I took up and examined some of the elm-wood blocks which had been thus treated and laid down in St. Clair street in 1870, and found them perfectly sound after elven years' exposure on the street.

Works were erected at Defiance and Milwaukee, where the timber and ties were treated with the Thilmany preservatives by steaming, vacuum, and pressure. But the results were not very favorable. At Defiance a solution of 1.5 in 100, and later one of 2 in 100, was injected with a pressure of 80 to 100 pounds until all the pores of the wood (as Mr. Thilmany says) were charged with the solution, when the boiler was filled with a 1½ per cent solution of chloride of barium. It is hard to conceive how the second solution could enter the pores already filled with the solution of sulphate of copper, and where the chloride of barium reached the first solution it left chloride of copper, the value of which as an antiseptic is uncertain, and some sulphate of barium inside of the wood, which could do neither good nor harm. The treatment of the paving blocks at Cleveland was evidently more rational; because by the Boucherie process the wood was well impregnated with sulphate of copper, and the soaking in chloride of barium only produced an interchange near the ends, where the formation of the insoluble sulphate of barium was of the greatest benefit in stopping up the pores to some extent, and if not preventing, at least impeding, the ingress of water and the washing out of the sulphate of copper from the inside.

Mr. Thilmany later used sulphate of zinc, instead of copper, in connection with chloride of barium, but the process does not appear any more rational. If the interchange of the chemicals throughout the lumber could occur, it would leave the wood impregnated with chloride of zinc and sulphate of barium; but, as such a complete interchange is impossible, part of the sulphate of zinc would undoubtedly remain unchanged, and as its antiseptic powers are not established, the result as to preservation must be uncertain.

2. *The Wellhouse process.*—Another device for preventing the removal of the zinc chloride has been invented by Mr. Wellhouse and is extensively used. It is based

on the fact that glue and tannin, brought together in proper proportions, will form a substance resembling leather. The timber is steamed in the usual manner, inclosed in a vacuum, then impregnated by pressure with a solution consisting of chloride of zinc and glue, and afterwards subjected to a bath of tannin under pressure. The impregnation with glue, it is claimed by the president of the company using this process, will destroy all tannic acid within the wood. But the benefit derived from this chemical combination is not apparent, since tannin is rather a preservative than otherwise. The bath of tannin, the president further states, precipitates the glue remaining in the outer pores of the wood, retaining a greater percentage of chloride of zinc in the wood than would be the case if it were simply Burnettized. But while the latter claim may be substantially correct, it remains to be seen whether the introduction of an uncombined organic substance into the inside pores will prove favorable to preservation.

The question whether the zinc-tannin process gives better results than the ordinary Bethell process will be decided within a few years, as a number of works for treating ties by this process have lately been constructed by the Atchison, Topeka and Santa Fe Railroad at Las Vegas, N. Mex., and by the Union Pacific Railroad at Laramie, Wyo., and the process is also used for preserving ties for several railroad companies at the Chicago works of the company.

The works at Santa Fe, which have within a year been erected on the plans and partly under the supervision of Mr. O. Chanute, C. E., are constructed and operated in accordance with all the requirements of the best modern practice. At the Las Vegas works an accurate and full record is being kept of all the operations and of all expenditures, more complete than has ever been approached, so far as I know, in this or probably any other country, and which, when published in full, will give more trustworthy information as to the cost of wood preservation than has heretofore been obtainable.

The data contained in these reports, which have been kindly furnished to me through Col. Edgar T. Ensign, forestry commissioner of Colorado, have been very useful in determining the comparative cost of the several processes now in use for the preservation of wood.

Whether the use of glue and tannin in connection with the zinc chloride will prove a success or not, the works erected under Mr. Chanute's directions and the methodical system of operating them initiated by him will do as much for the proper preservation of timber by mineral salts as Andrews, at Boston, and J. W. Putnam, in the South, have done for the proper application of the creosoting process.

3. *The zinc-gypsum process.*—The process was patented by Mr. Hagen, of St. Louis, and is used by the American Wood Preserving Company. In this process the timber is impregnated with a solution containing both chloride of zinc and gypsum. When the water of the solution evaporates the gypsum crystallizes and is expected to stop up the pores of the wood, and thus prevent the washing out of the zinc chloride. The question arises whether a substance soluble in water to some extent, like gypsum, can be expected to permanently stop up the pores of the wood against the ingress and egress of water. It seems hardly possible that the gypsum would answer the purpose. The best that can be said for this process is that if the addition of gypsum does no good it can not do harm, and if the wood is impregnated thoroughly with a solution of chloride of zinc and gypsum it will last as well at least as wood simply Burnettized.

4. *The zinc-creosote process.*—A process has lately been proposed by Mr. James T. Card, president of the Wood Preserving Works at Chicago, Ill., viz. to impregnate the timber first with chloride of zinc, and after partially removing the moisture from the wood to inject dead oil through the outer portions of it, thereby securing, as Mr. Card states, "all the benefits derived from the oil when lumber comes into contact with the ground, as well as insuring thorough treatment of the wood, through chloride of zinc, which is protected by the oil surrounding it, thus preventing its being chemically changed or washed out."

The process seems rational, and would probably answer a good purpose, if the necessary time and money can be spared to thoroughly dry the timber after impregnating it with zinc chloride and before injecting the oil.

COST OF PRESERVATION.

In order to make a fair comparison of the cost of treatment with the different antiseptics now in use, I will assume that the same kind of timber and the same form, viz, that of hard railroad ties, each containing 3.5 cubic feet, is to be treated, and that the quantity of antiseptic solution used and the strength of the solution are to be in conformity with the best practice, as developed by experience in plants of given size.

(*a*) *Creosoting.*—Assuming that two injection cylinders are to be used, each 100 feet long and 6 feet in diameter, the total volume of each cylinder will be 2,800 cubic feet, and it will have a capacity of nearly 1,400 cubic feet of timber (making allowance for volume of cars and interstices). The total plant required would cost, say, $80,000. If it takes twelve hours for a run, 5,600 cubic feet or 1,600 ties (of 3.5 cubic feet each) can be treated per day; or, say, 500,000 ties or 1,750,000 cubic feet can be treated in a year.

Taking the interest on capital (including repairs and renewal) at 10 per cent, the item of interest on plant will be $8,000, or 1.6 cents per tie.

Assuming the proper quantity of dead oil at 7 pounds per cubic foot, or 24.5 pounds per tie, and the cost of the oil at 0.8 cents per pound, the cost of material will be 19.6 per tie.

The cost of labor and fuel chargeable to treatment alone, judging from the accounts kept at Las Vegas, may be taken at about $15 per run, or, as 400 ties are treated at once, 3.75 cents per tie, or 1.07 cents per cubic foot of timber. The total cost of creosoting a tie would be, therefore:

	Per tie.	Per cubic foot.
	Cents.	*Cents.*
Interest on capital	1.6	0.46
Material	19.6	5.6
Labor and fuel	3.75	1.07
Total	25.00	7.1

The cost of transporting the ties to and from the works would of course have to be added, and profit, if the work is done by contract.[1]

I may mention that the above price for the dead oil is smaller than has been generally assumed, this because lately I have been offered dead oil at one-third of a cent per pound. At that price the cost of creosoting would be only about 14½ cents per tie.

If piles or timber were to be creosoted and impregnated with 20 pounds per cubic foot, it would take about sixty hours for a run, and the total number of runs per annum would be 240 (with 2 cylinders); the number of cubic feet of timber treated per annum, 350,000; the labor and fuel per run, $60, and the total cost of treating 1 cubic foot of timber; interest on plant, [illegible] = 2.3 cents per cubic foot; material (20 pounds, at 0.8 cent), 16 cents; labor and fuel, 4.3 cents; total, 22.6 cents, or about $19 per 1,000 feet, B. M.

(*b*) *Kyanizing.*—If the impregnation is to be carried out in the ordinary way, by steeping, and if the works are to be of sufficient capacity to treat 250,000 ties per annum, or, say, 800 ties, equal to 2,800 cubic feet of timber per day, and if the steeping is to be continued for seven days, there must be tank room for, say, 20,000 cubic feet of timber. Allowing 1.3 cubic feet of tank room for 1 cubic foot of timber, the total capacity of the tanks required will be 26,000 cubic feet, and if tanks 50 feet long, 7.5 feet wide, 5 feet deep are used, about 14 tanks will be required.

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[1] See note of cost of creosoting in France on page 73.

The plant would cost probably $10,000, and on 250,000 ties the charge for interest on plant would be (at 15 per cent, including repair and renewal) 0.6 cent per tie.

If 0.06 pound of bichloride of mercury is used per cubic foot, or 0.21 pound per tie (of 3.5 cubic feet), and the sublimate costs 50 cents per pound, the cost of material is 50 × 0.21 = 10.5 cents per tie. Labor and fuel would be about 3.5 cents per tie, and the total cost of kyanizing:

	Per tie.	Per cubic foot.
	Cents.	*Cents.*
Interest on capital	0.6	0.17
Material	10.5	3.00
Labor and fuel	3.5	1.00
Total	14.6	4.17

Bridge timber would have to be steeped during two weeks instead of one, and as therefore only half so much lumber could be treated as in the case of ties, the interest on capital would be doubled, the cost of material and labor remaining the same; the cost of treatment per cubic foot would therefore be increased only about one twenty-fifth, and would be 4.34 cents per cubic foot.

(*c*) *Chloride of zinc.*—If ties are to be impregnated by steaming, vacuum, and pressure, the cost of plant required (in connection with two injecting reservoirs) is about $40,000. Assuming the time used for one run at ten hours, 60 runs could be made per month with each cylinder, or 120 runs with the two cylinders, or 1,450 runs per annum. Taking 400 ties per run, the total number of ties which could be treated in a year would be 580,000, equal to, say, 2,000,000 cubic feet of timber. Allowing 10 per cent interest on cost of plant will give $4,000, or $\frac{400000}{580000}$ = 0.69 per cent tie, or 0.2 per cubic foot. The cost of concentrated chloride of zinc (specific gravity 1.5) is about $2.60 per cubic foot. If the solution has a strength of 1 in 60, 1 cubic foot of it will cost 4.3 cents, and if the wood takes up 33 per cent (by vol.) of the solution per cubic foot, it will require one-third cubic foot of the weak solution, costing 4.3, $\frac{260}{180}$ = 1.44 cents per cubic foot of lumber, or 5 cents per tie. Labor, at $10 per run, will cost $14,500, or 0.72 cent per cubic foot, or 2½ cents per tie. The total cost of this mode of preservation will therefore be:

	Per tie.	Per cubic foot.
	Cents.	*Cents.*
Interest on plant	0.69	0.2
Material	5.04	1.4
Labor and fuel	2.52	0.7
Total	8.25	2.3

(*d*) *Zinc-tannin.*—If, in addition to chloride of zinc, glue and tannin are used, the cost of material is increased by 2.5 cents per tie, and the cost of labor and fuel one-fifth or 0.5 cent per tie, making the total cost 11.26 cents per tie, or 3.2 cents per cubic foot.

(*e*) *Sulphate of copper.*—If a solution of sulphate of copper, 1 in 100, was to be injected by the same process, the change in cost would be in interest on plant and cost of material. As such works would cost about $60,000, the item of interest would be increased by one-half. As to cost of materials, sulphate of copper can now be bought at 7 cents per pound. Adding 99 pounds of water, 100 pounds, or 1.5 cubic feet, of the solution will cost 7 cents, or 1 cubic foot 4.6 cents.

Again, if one-third cubic foot of the solution be injected, the cost of material per cubic foot of wood will be 1.5 cents and the cost per tie 5.25 cents. The total cost of preservation would then be:

	Per tie.	Per cubic foot.
	Cents.	*Cents.*
Interest	1.05	0.3
Material	5.25	1.5
Labor and fuel	2.5	0.7
Total	8.80	2.5

(*f*) *Solutions of chloride of zinc, or sulphate of copper, injected by the Boucherie process.*—To treat 800 ties per day with zinc direct (pressure) by the Boucherie process would require an investment of capital of about $5,000. The interest on this sum at 20 per cent (including repairs and renewal) would be $1,000, or on 250,000 ties 0.4 cent per tie.

The quantity and cost of the chloride of zinc and sulphate of copper would be the same as when treated by the modern process, plus one-quarter for loss of solution from treating round sticks and from leakage. The labor would be 3½ cents per tie, and the total cost:

Antiseptic.

	Cost per tie.	
	Chloride of zinc.	Sulphate of copper.
	Cents.	*Cents.*
Interest	0.40	0.40
Antiseptic	6.25	6.56
Labor	3.50	3.50
Total	10.15	10.46

If the impregnation is to be produced by suction the cost of plant will be $12,000, the cost of the antiseptic the same as before, and the cost of labor also the same, since, although it requires two men to attend to the same number of logs which one man can attend to in the direct Boucherie process, the treatment is completed in half the time.

The cost of preservation by this method is, therefore, as follows:

Antiseptic.

	Chloride of zinc.		Sulphate of copper.	
	Per tie.	Per cubic foot.	Per tie.	Per cubic foot.
	Cents.	*Cents.*	*Cents.*	*Cents.*
Interest, repairs, and renewal, 20 per cent	0.96	0.28	0.96	0.28
Antiseptic	6.25	1.80	6.56	1.90
Labor	3.50	1.00	3.50	1.00
Total	10.71	3.08	11.22	3.18

Recapitulation of cost of preservation of railroad ties with different antiseptics and methods.

[Volume of ties, 3.5 cubic feet.]

Antiseptics.	Method of treatment.	Total cost.	
		Per tie.	Per cubic foot.
		Cents.	*Cents.*
1. Dead oil	Modern method	25.00	7.13
2. Bichloride of mercury	Steeping	14.60	4.17
3. Chloride of zinc	Modern process	8.25	2.30
4. Chloride of zinc and tannin	......do	11.25	3.20
5. Sulphate of copper	......do	8.80	2.50
6. Chloride of zinc	Direct Boucherie	10.15	2.90
7. Sulphate of copper	......do	10.46	3.00
8. Chloride of zinc	Boucherie (suct.)	10.71	3.06
9. Sulphate of copper	......do	11.22	3.18

As before stated, these estimates do not embrace the hauling of ties to and from the works. If the ties are destined for a new road just built the preservation of ties by processes 2, 6, 7, 8, and 9, in which the plant can be moved from one place to another, saves the carrying of the ties to distant works for treatment. No. 2, however, requires seasoned wood, and does not, therefore, offer as great advantage as the others. The entire cost of this transportation might, in some cases, amount to 5 or even 10 cents per tie.

CONCLUSION.

By Howard Constable, C. E.

The practicability and economy of wood preservation have been brought into question often, because the processes have been conducted by dishonest contractors or have been based upon some unwarrantable theory rather than upon any scientific principles. Nevertheless, many successes have been achieved and improvements have been made in the details of treatment and in mechanical contrivances to meet the conditions peculiar to this country. The table of experiments on page 281, in addition to those mentioned by Col. Flad, is certainly encouraging.

Both here and abroad the durability of wharf and other timber subject to severe exposure has been and can be at least doubled. The durability of piles and other timber subject to the attacks of the sea worm Teredo can be prolonged three or four times. The possible economy resulting from the use of treated hemlock ties instead of white oak in their natural condition has been estimated by Mr. O. Chanute as follows: For a road with about 2,000 miles of track, containing about 5,000,000 ties, $250,000 in first cost every twelve years, and $250,000 each year in the average charge for renewal of ties. Some moderate-sized roads use as many as 400,000 ties a year, and have to get from one-quarter to one-half of them from other territory than their own, which, of course, results in the railroads putting great obstructions to the shipping of ties out of their own region, and necessitates going to great distances for the extra supply.

A few are familiar with all these facts, but the majority, and the economists or business men, frequently realize them only partially, and do not appreciate the importance of the subject to themselves. We shall be accomplishing much if we aid in giving these persons a comprehensive and clear idea of it in its general bearings.

One of the first things to be clearly understood is that the field of wood preservation is a very large one, embodying many natural and artificial conditions somewhat different in each particular locality and case. Everyone can not preserve wood with advantage. It can not yet be done cheaply enough for ties on a new road in a heavily wooded district, any more than we could use stone for depots in such a region.

Nor is there any "cure-all" process by which any wood for any and every purpose can be preserved. Piles, which are cut to pieces by the *Teredo* within two years, require different treatment from ties to be placed in an ordinary roadbed, as the method of handling and transporting perishable freight must differ from that of ordinary freight, necessitating more care and expense. Any system to be adapted to a variety of work and to give promise of economical results must have the harmonious cooperation of all concerned in its operations and faithful attention to details. Each one in any way connected with the work should have a general understanding of it, and a precise knowledge of his own particular duties and the limits to be observed. If this is not the case the purchasing agent may contract for timber quite unsuited to the purpose for which it is procured; the superintendent may overlook the importance of ample facilities of operation; the engineer may not comprehend the degree of treatment required, and the inspector and workmen may become careless, and so ruin the work.

The need of intelligent cooperation is here emphasized because it has been neglected frequently and caused processes in themselves good to be attended with unsatisfactory results.

If a business man—the president, perhaps, of some company—thinks the subject of wood preservation may have in it some benefit for him, or those whom he represents, his main inquiries are: What does it amount to? Will it pay? Will it make a conspicuous item of economy? How will it affect our policy and dealings with others? Is it practicable in our case?

The manager asks somewhat the same questions, but inquires further: What are the conditions and necessities in our case? What is the best process and its cost? What are the conditions for success? What facilities have we? What rules shall be laid down?

The engineer or foreman in charge wishes to know what precisely is the composition of each ingredient, what is the order and time of each step in the process, what are the requisites and facilities, and what standard must be exacted in order to insure success.

Thus it becomes plain how the physical and commercial divisions of the subject interlace and require to be in accord. In order to select a process and lay down rules for the guidance of all connected with it, it is necessary to decide what purpose and exposure the wood is to be subject to, then to ascertain accurately all the conditions which prevail in the special case, and to determine the length of life that should be secured. Questions like the following will come up naturally and almost necessarily for answer: What is the name, quality, and cost of the wood to be used; its use and exposure; nature of soil and water; average length of life, sources of injury, such as *Teredo,* notching and framing, cutting by the rail, etc.; destroyed by what? Cost of renewals. Available woods for treatment. Cost of the same. Probable quality and condition. Receiving point. Distributing point. Location for preserving works. Capacity of plant. Cost of plant. Cost of operating.

I may be permitted to quote from the recent and very instructive report on the preservation of timber, made in 1885, by a committee of the American Society of Engineers, after a careful and protracted examination of the subject:

"In view of the differing cost of the various antiseptics used, and of the price of timber in this country, where it is still much cheaper than in Europe, we believe that the method to be selected for preserving wood, if any, depends almost wholly upon its proposed subsequent exposure.

"If the timber is to be exposed, in sea water, to the attacks of the *Teredo navalis* and *Limnoria terebrans,* there is but one antiseptic which can be used with our present knowledge. This is creosote, or 'dead oil,' and the amount of it necessary depends upon the activity of the *Teredo,* or rather upon the length of time during the year when the temperature of the water renders them active.

"In our northern harbors, probably 10 to 12 pounds of creosote to the cubic foot of timber are sufficient, but in southern seas it is probably necessary to inject from 14 to 20 pounds per cubic foot.

"Whether it will pay to do this depends upon so many local circumstances in each case that this can not well be discussed here. If the timber is to be exposed in a very wet situation, creosoting is also the best process to use. It will cost from $10 to $20 per 1,000 feet, b. m., or 35 to 60 cents per tie.

"The selection of the oil, as well as the quantity, is of importance. It was formerly believed that the antiseptic properties of dead oil arose from the presence of carbolic and cresylic acid, but a very able paper by Mr. S. B. Boulton, the leading authority on creosoting in England, read before the British Institution of Civil Engineers in 1884, seems to establish the fact that the preserving properties of dead oil, aside from the mechanical effect in keeping out moisture, are chiefly due to 'acridine,' or one of the alkaloids or bases now known to exist in creosote oils.

"If the exposure is to be that of a railroad tie, creosoting is doubtless the most perfect process to use; but in view of the expense, it may be preferable to use a cheaper process, dependent somewhat upon the location, as away from the seaboard creosote is not available, and transportation is expensive.

"Sleepers of Baltic fir, unprepared, 9 feet long and 10 by 5 inches, generally cost in England about 90 cents each, unloaded, grooved, and piled; and creosoting adds about 24 cents to this. So that the sleeper costs about $1.14 ready to go into the track, and is there laid with a chair under the double-headed rail, so that the latter does not cut into the wood. These sleepers, therefore, last eighteen to twenty years, while in this country they would probably be cut into by our foot rail in from twelve to sixteen years; and, moreover, as the first cost of our ties, of corresponding timber, say, hemlock or mountain pine, is only from 25 to 35 cents, we can not afford to spend an equal sum in preserving them; and creosoting is notoriously more expensive here than in England.

"With our present knowledge, and as a result of this investigation, we believe that burnettizing is the advisable process to use for ties at present in this country. This, if well done (and it is nearly useless to do it otherwise), will cost 20 to 25 cents per tie, and a discussion of the economical results to be expected therefrom will be found in Appendix No. 17.

"Good results may be accomplished with sulphate of copper, but not only does this salt render wood brittle (more so, it is believed, than chloride of zinc), but as the copper attacks iron vessels, its use necessitates preserving cylinders of copper, and requires an expensive plant.

"The great defect of all mineral salts is that they are easily soluble in water, and so wash out in time, and leave the timber unprotected. Hence the many attempts to patent some method of retaining them in the wood. What these may be worth must be determined by time, but the desirable combination for this country would seem to be the impregnation of the inside of the tie with some metallic salt to poison the germs of decay, and a thin coat of creosote outside to repel the intrusion of moisture.

"If the timber is to be exposed in a comparatively dry situation, as in bridges, a trestle, or a fence, the results of this investigation indicate that Kyanizing is a good process to use. It does not seem to impair the strength of the timber as much as Burnettizing, and the latter accordingly is not recommended for those parts of structures (chords, ties, etc.) which are to bear tensile strains.

"Kyanizing costs about $6 per 1,000 feet, B. M., and success with it can not be expected unless the work be well done. Caution will need to be observed in carrying it on, as corrosive sublimate is a violent poison.

"*Conditions of success.*—Your committee will therefore attempt to state the principal conditions to be observed to achieve success, so far as they have been disclosed by this investigation.

"(1) Select the appropriate process, in view of the subsequent intended exposure of the timber.

"(2) Select the more open-grained, porous, and sappy varieties of wood to operate upon.

"Antiseptics penetrate but little into the dense structure of white oak, burr oak, and yellow or heart pine, and are of doubtful utility for white pine, chestnut, or spruce, while they readily impregnate and preserve the following varieties of wood: Hemlock, sweet gum, mountain pine, loblolly pine, black oak, red oak, gray oak, water oak, beech, popular, ash, sour oak, cottonwood, maple.

"The cheap woods, on the contrary, can be made to outlast the best woods in their natural state by a thorough artificial preparation.

"(3) For railroad ties it will be advisable to select the harder kinds of wood to guard them against cutting into by the rails, especially upon curves. Preservation, however, materially adds to the natural hardness of timber, and it is found to resist cutting by the rail, under ordinary traffic, from twelve to sixteen years.

"(4) Extract the sap and water, as far as practicable, before injecting the preservative. It is obvious that a liquid solution can not be forced in unless there is a place for it, and yet most of the failures of valuable methods can be traced to neglect of this obvious requirement. Timber must be well seasoned, either naturally or artificially, before the antiseptic is injected, except in the case of the Boucherie process, which can only be applied to freshly cut logs.

"The Europeans operate, as has been stated, upon timber which has been cut and seasoned six months or more, and hence they find little trouble in injecting the solutions. In this country we must operate chiefly upon green or freshly cut timber, and hence must resort to steaming, if we use the pressure method of injection. Very good results are accomplished by steaming, but the work must be well done, and at such heat and pressure as not to injure the fiber.

"(5) Put in enough of the antiseptic to accomplish the desired result, and make sure that its quality and strength are such as neither to injure the fiber of the wood nor to leave it unprotected.

"(6) After the wood is prepared allow it to dry as much as practicable before using. Its durability will be materially increased by getting rid of surplus moisture.

"(7) Let there be no undue haste in carrying on the work. This is sure to result in unsatisfactory preparation.

"(8) In laying prepared ties or timber in the track protect them from moisture or water, as far as practicable, by draining the roadbed.

"(9) Contract with none but reliable parties. As an inspection subsequent to the doing of the work, short of chemical analysis, does not establish the fact whether it has been well done, and the results can not be detected for some years, there will always be a great temptation to do bad or careless work under contracts. The safe course, therefore, for those who decide to have timber preserved is either—

"(*a*) To do the work themselves, under the supervision of experts;

"(*b*) To contract it at a sufficient price to honest and skillful parties, keeping an inspector at the works to note the daily working when the magnitude of the order will warrant it; or,

"(*c*) Contract the work on such terms that the profits shall depend upon the results accomplished in preserving the wood against decay.

"*Will it pay?*—The question as to whether it will pay to preserve timber against decay seems to have been answered very positively in the affirmative in Europe. There seems to be, indeed, no longer any question there about it; preservation is looked upon as quite a matter of course, and public works which fail to avail of it are alluded to as neglecting an important economy.

"In this country, preservation of wood (except in an experimental way) has been the rare exception, but the time has probably arrived when, in many sections, an economy of 20 to 50 per cent a year can be obtained in the maintenance of timber structures and cross-ties by preparing them artificially to resist decay, while in other sections timber is still too cheap to warrant spending money to preserve it.

"This depends upon the price. Thus, where a white oak tie costs 25 cents and lasts eight years, if we spend 25 cents in preparing it so that it will last sixteen years, we but double the life as well as the cost, and save only the expense of taking the old tie out and placing the new tie in the track at the end of the first eight years, if the price of the ties in the meanwhile continues the same.

"If, however, the oak tie costs 75 cents, and we can substitute a hemlock tie, which unprepared would last three and a half years, and cost 30 cents, and by preparing it extend its life to twelve years, at an additional cost of 25 cents, or even more, we then have a notable economy, both in first cost and in duration.

"In the case of piles, which are cut off by the teredo in one or two years, as occurs in our Southern harbors, the case is plain. They must be creosoted, or great waste and increased expense will result. In cases where they last eight to ten years, as in some northern sections, it will depend partly upon the value of the structure which the piles sustain whether it will pay to creosote them or not.

"In the case of bridges and trestles, much will depend upon the exposure, and the cost of maintenance, as well as upon the proximate exhaustion of suitable timber in the vicinity, and upon contemplated permanent renewals; while in the case of buildings, platforms, floors, etc., the ordinary wear from traffic will also have to be taken into account.

"The most important factor will be the exposure (wet or dry) and consequent rate of decay. Thus all brewers find it very economical to preserve their floors; and mills, bleacheries, dyehouses, etc., largely resort to artificial preparation of timber because of their exposure to slopping of water, and consequent moisture in heated apartments.

"The engineers and managers of the several works, therefore, will have to figure up for themselves, in view of the local circumstances of their case and the present and prospective price of timber, whether the economy of artificial treatment is sufficiently attractive to induce them to resort to it.

"The great consumers of timber are the railroads, and the managers of such enterprises have to be governed by a good many considerations, both of finance and of expediency, besides those of eventual economy.

"Hitherto, aside from the past cheapness of timber, the principal objections to its preparation against decay have been the lack of information as to what results could be confidently expected, and the conflicting claims of the promoters of various modes of treatment, each of whom represented his process as absolutely the best under all circumstances.

"Railroad managers naturally want to obtain immediate returns. They do not like to burden the revenues of the current year for the benefit of future administrations, and they are with reason jealous of every dollar that goes out now, even if it promises to save \$2 or \$3 in the future; yet, now that close competition requires every possible economy to be availed of, that railroads must more largely depend upon saving money in their maintenance, in order to continue or to resume their dividends, and that companies in good standing can obtain new capital for expense-saving appliances at 4½ or 5 per cent a year, the time has probably arrived, in view of advancing prices and scarcity of timber, when some leading railroads will take steps to preserve it.

"Privy Councillor Funk estimates that in 1878, out of 60,000,000 sleepers on the German railroads, 25,000,000 were impregnated, and that even with the extraordinary length of life stated for unprepared ties (13.6 years for oak and 6.1 for fir and pine), had the remaining 35,000,000 ties been impregnated there would have been a resulting economy of about \$1,000,000 a year, or some 33 per cent on the cost of renewals.

"This estimate is understood as having resulted in a material extension of tie-preserving in Germany, notwithstanding the fact that metallic ties have already been largely introduced in that country.

"As regards the latter, a simple calculation shows that the time has not yet arrived when they can profitably be introduced in this country. They will cost, laid in the track, about \$2.50 each, and were they to last forever (the estimated life in Germany is twenty to forty years) the interest on the cost, at 5 per cent, would be 12½ cents a year a tie, or more than the annual charge of an unprepared white oak tie, costing 77 cents in the track, and lasting seven years.

Record of successful American experiments in wood preservation.

No.	Locality.	Year.	Process.	Material treated.	Subsequent exposure.	Results.	Authority.
1	Vermont Central R. R	1856	Bethell	Hemlock ties	Railroad track	Success, 1882	J. W. Hobart.
2	Chicago, Rock Island and Pacific R. R	1860	do	Timber	Howe truss	do	Hugh Riddle.
3	do	1866	do	Ties	Railroad track	Success	M. Alexander.
4	Lehigh and Susquehanna R. R	1867	do	do	do	Success, 1882	L. L. Buck.
5	New Orleans	1872	Boiling	Paving blocks	Paving	do	T. Forstall.
6	East River bridge	1872	Steaming	Plank	Caisson	do	F. Collingwood.
7	Boston	1872	do	do	Floor	do	Blake Manfg. Co.
8	Galveston	1874	do	Pine blocks	Stable	do	W. E. Gregory.
9	New Orleans and Mobile R. R	1876	do	Piles	Teredo	do	J. W. Putnam.
10	Bound Brook R. R	1876	Hayford	Ties	Railroad track	do	E. R. Andrews.
11	New Orleans and Mobile R. R	1876	Steaming	Timber	Bridges	do	J. W. Putnam.
12	Delaware Bay	1878	do	Pine blocks	Teredo	do	W. Ludlow.
13	Philadelphia and Reading R. R	1878	do	Ties	Railroad track	do	W. Lorenz.
14	Charlestown, Mass	1879	Thilmany	Spruce plank	Sidewalk	Success to 1882	S. G. White.
15	Hudson River R. R	1869	Hamar	Ties	Railroad track	do	E. W. Vanderbilt.
16	Alexandria	1840	Steeping	Timber	Bridge	Success to 1862	W. R. Hutton.
17	Lowell Canal Co	1848	do	do	Bridges	Continued success	J. B. Francis.
18	Philadelphia and Reading R. R	1850	do	Pine timber	do	do	J. D. Steele.
19	Blackstone bridge	1854	do	do	Bridge	do	W. H. White.
20	St. Louis, Mo	1879	Burnettizing	Gum blocks	Pavement	do	H. Constable.

(2) REPORT ON WOOD-CRESOTE OIL.[1]

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The southern pine (*Pinus palustris*, Linn.) has already made a brilliant record for itself in the past through its valuable products in the shape of turpentine, pitch, tar, and resin; but there remains for it a much more brilliant career in the future through its newer products, wood-cresote oil and pine-leaf fiber, the oil being used mainly for preserving lumber, and the fiber for the manufacture of pillows, mattresses, and carpet matting.

The wood-cresote oil industry is at present carried on in the South mainly by the Carolina Oil and Creosoting Company and Creosote-Lumber and Construction Company, of Wilmington, N, C., and the following description of the products and processes is based upon the practice of the latter manufactory.

Creosote is a general name applied to the oil products obtained by the destructive distillation of wood, coal, and other carbonaceous fuels after the temperature has risen above 200° or 300° F. If obtained by the distillation of coal, or coal tar, this creosote is termed "dead oil," or coal tar creosote oil; if obtained from the distillation of wood, or wood tar, it is termed wood-creosote oil.

Heavy-resined, "fatty pine" wood, subjected to a heat of from 200° to 760° F., within closed iron cylinders, yields by distillation and condensation: (1) a wood gas; (2) a small amount of wood naphtha; (3) a large amount of pyroligneous acid; (4) a large amount of wood-creosote oil; (5) a small amount of wood bitumen; and (6) a large amount of charcoal. Nine cords of good wood will yield a few gallons of naphtha and bitumen, 14 barrels of oil, 10 barrels of acid, and 168 barrels of charcoal.

The wood-creosote oil produced by this process is a dark, brownish, black oil, slightly heavier than water (3° to 4° Beaumé), with a strong creosote odor, and possessing valuable antiseptic properties. Upon analysis it is found to contain about 5 per cent of tar acids, about 15 per cent of lighter oils, and 80 per cent of heavy oils, which are insoluble in ether, fresh, brackish, or salt water. This oil is an efficient poison to minute animal and vegetable life, and possesses an odor apparently intensely disagreeable to such life; it thoroughly repels moisture, and its tar-acids possess the power of coagulating albuminous and other fermentable matter. When properly prepared for such use it has been found to be an excellent insecticide to be employed on trees and smaller plants, especially for the destruction of larvæ attacking rose bushes, as also for destroying vermin on animals, in the cracks of floors, and in wooden buildings, and one of the best possible oils for preserving lumber and piling.

Experience in England[2] and in the United States[3] is unanimous in agreeing that creosoting is the only reliable method, so far as tried, for preserving timber when exposed to salt water (and the Teredo worm), or to alternations of wetting and drying by either fresh or salt water. This experience also shows that the preservation of the timber is due mainly to those creosote oils which require over 400° F. for their volatilization, and that the pure creosote (with less tar acids and with less light oils) gives the best results.

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[1] See also the paragraphs on creosoting in Part III.—E. E. R. T.

[2] See Proceedings of Institution of Civil Engineers for 1885.

[3] See Proceedings of American Society of Civil Engineers for 1885.

Wood-creosote oil is much less expensive, and in many ways much more valuable, than the ordinary dead oil or coal-tar creosote oil heretofore used for such purposes as the preservation of timber. Wood-creosote oil contains all the acids needed to properly coagulate the albumen and sap which may be left in the timber, and to thoroughly destroy and prevent all further animal and vegetable life; it is of such nature that it will penetrate the wood both deeply and thoroughly; it contains a large proportion of insoluble matter, and especially of those oils which volatilize only under a heat of over 400° F.; and, being derived from wood, it is especially adapted to use with wood.

In all these particulars, as well as in its less cost,[1] the resinous wood-creosote oil is superior to the bituminous coal-tar creosote oil (or dead oil), and, dollar for dollar, it will give far superior results in the preservation of timber from destruction and decay.

Applied with an ordinary brush to wooden or metal surfaces of all kinds, two coats of this oil (with an interval of two months between the applications) will effectually preserve these surfaces from wet and dry rot, from rust, and from the attacks of worms and insects. Forced into the wood by hydraulic pressure, this oil will fill all the pores of the wood and extend its coagulating and antiseptic effects entirely through the wood to its very center. The good results obtained by the use of this wood-creosote oil have been thoroughly tested by the experience of five years in Mr. Mark's shipyard, at Charleston, S. C., and at Mr. W. H. Northrop's bathhouse, at Greenville Sound, near Wilmington, N. C., both places being such that untreated wood is badly damaged in a single season by rot and by the ravages of the teredo. A log treated with this oil and driven into salt water at Key West, Fla., in October, 1885, by the United States engineers, in February, 1887, was found to be untouched by the teredo, although untreated logs were attacked by it in six weeks after they were driven. Similar results were obtained at about the same time by the United States engineers at Charleston, S. C., and at Pensacola, Fla.

The comparative invulnerabilty to fire possessed by wood that has been treated with this oil has been proved at the burning, in the fall of 1886, of the Atlantic and North Carolina Railroad wharf, at Morehead City, N. C., where the creosoted fender piles remained almost without damage by the fire, while the wharf and shed next to them were burned down entirely. Live coals and ordinary flames are unable to kindle any fire in wood impregnated with this wood-creosote oil.

The pyroligneous acid produced during or just before the distillation of the wood-creosote oil is a light-colored, vinegarlike liquid, slightly heavier (4° to 70° Baumé) than water, and also slightly heavier than the wood-creosote oil. This pyroligneous acid, in its crude and undiluted state, is an excellent and inexpensive disinfectant, immediately arresting putrefaction and preventing any further development of the disagreeable and unhealthy odors arising therefrom. It is equally if not more efficacious than carbolic acid, as well as being free from odor, which makes that acid so disagreeable (at least to many), and it is nearly or quite as efficacious as corrosive sublimate, and is free from the poisonous qualities of this chemical. It is an excellent remedy for skin diseases in animals; makes good vinegar and alcohol, and is said to preserve meats for an indefinite time. As a disinfectant it has been used in large quantities and with great success in the streets, stables, privies, etc., of Wilmington, N. C., under direction of the city authorities.

The charcoal produced by this process is one of fine quality and of remarkably even texture, well adapted for use in the smelting of iron, as well as for ordinary fuel. When finely pulverized (as at the Wilmington works) it can be advantageously used in the place of lampblack in the manufacture of paints for the preservation of wood, as also for the preservation and insulation of metals.

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[1] It is to be regretted that the cost of treating wood with this wood-creosote oil has not been given, so as to admit of a comparison on a financial basis with the processes outlined by Col. Flad. An effort to obtain the same has so far proved unsuccessful.—B. E. F.

As will be seen from the above the most important product of the distillation of pine wood is the wood-creosote oil, and the most important use (commercially) of this oil is as a preservative of timber and lumber.

The general features of the process of distillation and subsequent use of this oil are as follows:

Ordinary "light wood" (or "fatty pine" wood) is cut up into sticks of about 4 feet in length, and about 5 cords of these sticks closely packed inside of a large cylindrical iron retort. The doors of this retort are then closed and hermetically sealed. A fire is then built in the furnace under the retort, and the heat and flames are directed as uniformly as possible all around the outside of the retort. As the temperature inside the retort increases from 100° to 700° F. the liquid and some of the solid portions of the wood are converted into gas and vapor, and pass out of the retort through a copper "worm" inclosed in a cold-water tank and are collected in the form of wood-gas, naphtha, acid, and oil. When the oil ceases to run, the fires under the retort are put out, the bitumen is drawn off through a tube coming from the bottom of the retort, and the latter is then allowed to cool off. As soon as possible, therefore, the doors of the retort are opened and the charcoal raked out. The operation is thus finished, and the retorts are ready for a fresh charge.

Timber and lumber which is to be treated with this oil must be first prepared to receive it. Timber is taken directly from the river by large derricks, is landed on the wharf, is stripped of its bark, and then exposed to the sun for a week or ten days to dry. At the end of this time it is placed (one stick at a time) on trucks, is rolled into the carbonizing cylinder, is there exposed from about ten to twenty minutes to an intense radiated heat, and is then withdrawn charred to a depth of one-fourth of an inch, thoroughly dried to a depth of three-fourths of an inch, and thoroughly heated to a depth of several inches.

The carbonizing cylinder consists of a wrought-iron cylindrical tube about 21 feet long by 28 inches in diameter, set in a brick furnace, fired at the side and midway of its length, the cylinder being brought to a proper and uniform heat by means of a wood fire, the heat and flames of which pass by vertical and horizontal flues along and all around the cylinder. The cylinder is further provided with a small railroad track and iron carriage on the inside, for the convenient handling of the timber. Sawn lumber is not usually charred, but is sometimes kiln-dried or semicharred; the objection to the charring being that it destroys the sharp edges of the lumber. The charring or carbonizing of the process, therefore, consists in taking the timber and subjecting it to a dry radiant heat within the suitable cylindrical surfaces in such manner as to drive out of the timber most of its sap and albuminous matter (ordinarily about 5 pounds to the square foot), drying the inside of the timber, charring its outside, and leaving the wood with its pores open and in condition to be completely filled with the wood-creosote oil thereafter applied to it.

Charred timber, once thoroughly carbonized, will not crack under subsequent exposure to the sun and air. If further properly treated with wood-creosote oil it will withstand all attacks of atmosphere, moisture, and animal life, and will last for years anywhere.

This process for carbonizing and creosoting timber is such that it does not injure the fiber of the interior of the wood. It is one of the simplest, cheapest, quickest, most effective, and most successful processes so far known for artificially seasoning and preserving wet or green timber, in cases where the want of time or money do not allow a thorough natural seasoning of at least six months' exposure to the atmosphere. Although other and improperly applied methods of dry-heating and after-creosoting may render timber brittle under the pile driver, none of the timber so far carbonized and wood creosoted has proved objectionable from this cause. On the contrary, the wood creosote restores the toughness and elasticity to the charred wood, so that this method has given great satisfaction wherever used, as, for example, at Aspinwall, Panama, under the Panama Canal Company; and at Charleston, S. C., under the Northeastern Railroad Company; in both cases under circumstances extremely unfavorable to the life of the timber.

After the wood has been carbonized or kiln-dried it is loaded upon trucks, which, with their load, are rolled into the creosoting cylinders, respectively of 65, 75, and 90 feet in length, each with a diameter of 6 feet. The doors of the creosoting cylinder are then closed for from four to fifteen hours, during which time the temperature within the cylinder is raised by dry heat to from 140° to 160° F., a vacuum of from 9 to 24 inches is kept up by means of a vacuum pump, and the sap, albumen, and other impurities are thus thoroughly extracted from the wood and pumped out of the cylinder.

The vacuum pump is then stopped and a force pump put to work, by which the cylinder is filled with hot wood-creosote oil, under a pressure of from 65 to 100 pounds per square inch, this pressure being constant from four to eight hours, according to circumstances. By this part of the process from 8 to 20 pounds of oil are forced into each cubic foot of wood. The pressure is then relaxed; the unabsorbed oil is then run off into outside tanks, the doors of the cylinders opened, and the impregnated timber, still on its trucks, is rolled out.

This treatment with wood-creosote oil, as above described, has been favorably reported upon (March 18, 1886) by a special board of United States Navy officers; and the wood so treated has had an extensive use already upon the Government wharf at Charleston, S. C., at the jetties at Port Eads, in the M. T. and E. P. Inclined Railway at Cincinnati, Ohio, as well as in many other less important places and structures.

Treatment with this oil is especially valuable to wood that is to be used in the construction of bath houses, wharves, docks, quays, piers, railroad bridges, railroad trestles, wooden pavements, flats, lighters, scows, ship spars and masts, ship decks and bottoms, or used in railroad cross-ties, foundation sills for houses, piazzas, porches, floors, fence posts, and telegraph poles. No cases have yet been discovered where either rot or teredo has attacked wood that was thoroughly impregnated with this wood-creosote oil.

ADDENDA TO APPENDIX No. 1.

By B. E. FERNOW.

DESCRIPTION OF VARIOUS METHODS OF IMPREGNATION AS PRACTICED FOR THE PRUSSIAN RAILWAYS.

It may be of interest to note in detail the methods practiced in preserving railway ties for the Prussian railway service. Through the kindness of Mr. Holbein, manager of the Juls. Ruetgers Preserving Works, which impregnate most, if not all, of the ties of the Prussian railways—of the 60,000,000 ties annually laid, 48,000,000, or two-fifths, are treated—we are enabled to print the specifications as agreed upon between the railroad authorities and the impregnating works, as follows:[1]

A.—IMPREGNATION WITH CHLORIDE OF ZINC.

The process is divided into three operations: (1) The steaming; (2) the establishment of a vacuum; (3) the admission of the solution of chloride of zinc, with application of a pressure pump. The ties, on iron trucks, are run into the cylinder, which is closed air-tight, and are exposed to the influence of steam in order to remove or make innoxious the sap, which is apt to ferment, as well as to prepare the wood for the impregnating liquid. The steam has in addition the object of facilitating the reception of the greatest possible amount of the liquid, for which purposes it is necessary that the outer surface of the cross section be softened and the hardened sap at this cross section, which frequently, in combination with sand and dust, forms a coating impenetrable for fluids, be removed.

According to the season, the condition and species of the wood, the steaming must be continued for a longer or shorter time. The introduction of the steam from the boiler into the impregnating cylinder is to be conducted in such a manner that the steam pressure in the cylinder may reach 1½ atmospheres (21 pounds) in thirty minutes.

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[1] Jules Ruetgers Preserving Works.—This firm has impregnated during they ears 1849–1891 not less than 170,000,000 cubic feet, in which amount over 42,000,000 ties of oak, pine, and beech are represented. In 1891, 1,769,155 ties were treated with chloride of zinc and creosote, and 485,730 with tar oils alone. Altogether the method of employing zinc and creosote together seems to find more application than the others, the greater expense being offset by greater durability. With the coming year (1895) all the pine ties used by the Prussian railroads will be impregnated with this process. According to the report of one of the railroads, of 171,000 treated pine ties laid in 1885 only 29 had become unserviceable up to 1894, and these were not rotted.

With dry pine and oak ties it is sufficient to maintain this pressure in the cylinder for thirty minutes more. With fresh pine and oak ties the duration of the steaming must be prolonged in proportion. It would take longer time for the steam pressure to reach the 1½ atmospheres in the cylinder, and its pressure must be maintained for one hour longer.

The steaming lasts, therefore, with dry woods at least one hour, while with wet woods it must be prolonged to one and one-half hours or more, according to the time necessary to bring the pressure in the cylinder to 1½ atmospheres. With beech wood, no matter whether dry or fresh wood is used, the steaming is to be continued for three hours, under pressure of 1½ atmospheres, so that the heating of the wood in all parts to 100° C. is assured. The existence of the prescribed pressure will be indicated by a manometer connected with the cylinder.

At the beginning of the steaming a door at the lower side of the cylinder is to be opened in order to permit the driving out of the air in the cylinder until steam issues. This same aperture will be opened during the steaming from time to time, according to the progress of condensation of the steam, for the purpose of releasing the water. When the steaming is finished the steam is allowed to escape, and a vacuum of at least 60 centimeters mercury is established and is maintained for thity to sixty minutes, according to whether dry or fresh wood was used.

After this time, with continued vacuum, the solution of chloride of zinc, warmed to 65° C. or more, is allowed to enter the cylinder under the atmospheric pressure until it is full. Then the pressure pump is applied to produce a pressure of 6⅔ atmospheres for the time of at least sixty minutes, when the pressure is no longer necessary, under the instructions regarding the strength and quantity of liquid to be injected.

After this operation the liquid is allowed to run out.

The chloride of zinc used for the purpose must be as much as possible free from foreign substances, especially from an excess of acids, and at 14° R. must show a strength of 3° Beaumé. To control the perfect impregnation with chloride of zinc, it is agreed that a dry tie of round 0.104 cubic meter contents shall take up at least—

	Kilograms.
(*a*) For pine wood	30
(*b*) For oak wood	10
(*c*) For beech wood	30

And that an air-dry tie of about 0.090 cubic meter contents shall take up 27 kilograms, while air-dry timber is to take up per cubic meter (35.3 cubic feet)—

	Kilograms.
(*a*) Pine wood (19 pounds per cubic foot)	300
(*b*) Oak wood (6¼ pounds per cubic foot)	100
(*c*) Beech wood (19 pounds per cubic foot)	300

If the amount of liquid required can not be injected in the manner prescribed because the wood was too green or exceptionally dense, the liquid is to be strengthened in such a manner that the proper amount of water-free chloride of zinc is taken up as prescribed, namely, that to be contained in a 3° Beaumé liquid.

From this it follows that when, for instance, only 200 kilograms can be introduced into the 1 cubic meter of pine wood, the chloride of zinc bath must be made 4½° Beaumé. The samples of chloride of zinc for test shall be taken when issuing from the safety valve. When, according to the test, a strengthening of the fluid, by means of a bath of concentrated chloride of zinc, has become necessary, the fluid of the prescribed strength must have been in the cylinder for at least one-half hour. The determination of the quantity injected into the woods shall be made by weighing the woods directly before and after the impregnation, assuming that the difference of weights show the quantity of liquid injected.

Any deficiency in the weight will be deducted at the rate of 25 pfennig per 10 kilograms chloride of zinc liquid of 3° Beaumé.

B.—IMPREGNATION WITH CHLORIDE OF ZINC UNDER ADDITION OF "CARBOLIC ACID TAR OIL." (COAL TAR, CREOSOTE OIL, OR "DEAD OIL.")

The impregnation is carried out in the same manner as prescribed for the chloride of zinc process, and all prescriptions for this process remain the same. In addition, during the heating of the chloride of zinc solution there are added for each tie 2 kilograms, or for each cubic meter of wood, 20 kilograms of tar oil (1¼ pounds per cubic foot), containing 20 to 25 per cent of creosote or carbolic acid. The contents of sour oils (creosote or carbolic acid) will be determined by their solubility in an alkaline liquid of 1.15 specific gravity.

The mixing of the tar oil with the chloride of zinc is effected by a serviceable mechanical mixer under injection of steam.

C.—IMPREGNATION WITH CARBOLIC ACID TAR OIL ("DEAD OIL") WITH USE OF THE DRY-KILN.

This process is carried on in three stages: (1) The drying of the ties in the dry-kiln; (2) the establishment of a vacuum; (3) the introduction of the tar oil and application of the pressure pump.

The ties and timbers are run on iron trucks into a well-constructed dry-kiln, in which they are exposed to a gradually rising temperature up to 110° C. for at least eight hours, until no water vapors escape and the timbers are evenly heated. After this drying, the ties are at once transported while hot into the cylinder, which is thereupon closed hermetically.

Then a vacuum of 60 cm. mercury is established, which should be attained within thirty minutes and is to be maintained for thirty minutes more.

After this time the cylinder is filled with carbolic acid tar oil under constant application of the air pump.

After the cylinder is filled a pressure of 6⅜ atmospheres above the outer air pressure is established by the pressure pump and kept up for at least sixty minutes, when a continuation of the pressure is not any more needed to effect the prescribed injection of the tar oil.

To control the complete impregnation of the wood with tar oil, it is agreed that an air-dry normal tie of 0.104 cubic meter contents must take up in—

	Kilograms.
(*a*) pine wood	20
(*b*) oak wood	8.5
(*c*) beech wood	25

while timbers and other dimensions of air-dry ties are to take up per cubic meter:

	Kilograms.
(*a*) in pine wood (12 pounds per cubic foot)	200
(*b*) in oak wood (4½ pounds per cubic foot)	85
(*c*) in beech wood (15 pounds per cubic foot)	250

To determine the quantity of tar oil taken up, the ties are weighed first after the kiln drying and again after the impregnation. The difference in weight gives the quantity of tar oil taken up.

Should it be found that the amount of tar oil injected remains less than five-sixths of the prescribed quantity, the impregnation must be repeated. The quantity of tar oil finally deficient, according to the test, will be deducted at the rate of 10 marks per 100 kilograms.

The oil derived from coal tar must not contain more than a minimum of light volatile parts. The oils must be so heavy that the boiling point shall lie between 180° and 400° C., and mostly over 235° C.

The contents of sour ingredients (creosote or carbolic acid), soluble in concentrated alkali solution, must be at least 10 per cent. The oil, in spite of the high boiling point, must be liquid at 25° C. and free from solid ("smeary") ingredients to such an extent that, when poured upon a cross cut, it penetrates immediately without leaving anything but an oily residue. At the same time the tar oil must be of such a condition that after impregnation it will be nearly entirely retained by the wood. It must not contain, or only in small quantities, oils of a specific gravity below 0.92, while the specific gravity of the oil itself must not exceed 1.08.

There may be added to the coal tar oils, oils derived from brown coal, turf, or wood up to 25 per cent, if the same correspond, in the qualities recited, to the coal tar oil.

ROYAL RAILWAY MANAGEMENT,
BRESLAU, *March 25, 1887.* *Grotefend*
The CONTRACTOR,
BERLIN, *March 18, 1887.* JULS. RUETGERS.

The following "expert opinions" regarding the two methods of impregnation with chloride of zinc and tar oils, which were received through the kindness of Mr. F. Holbein, manager of the Juls. Ruetgers Impregnation Works, still hold good, although more than twenty years old, and are so clearly expressed that their reproduction here will not be considered out of place:

OPINION OF DR. HERMANN KOLBE, AT LEIPZIG, REGARDING IMPREGNATION WITH CHLORIDE OF ZINC.

The directory of the Leipzig-Dresden Railway Company has asked me to express an expert opinion as to whether the usefulness of wood impregnation is scientifically tenable; and if so, how the rotting of wood is impeded.

The impregnation of wood has for its object to impede the rotting of the same; that is, make the progress of rotting slower, or to delay it at least for a longer time. This object would be attained in the most complete manner if the material used for impregnation form with the wood fiber chemical compounds, which are not any more subject to rot, about in the manner in which the easily rotting animal skins combine with the tannic acid into rot-resisting leather.

The substances which are mostly used for impregnation of wood—chloride of zinc and creosote—do not, as far as our experience goes, have this property, and therefore have been by many considered useless for the purpose.

I can not agree to this opinion after having examined the impregnation works at Dresden and having chemically analyzed the ties impregnated with chloride of zinc.

The wood fiber itself is a substance but little affected by rot. It is the nitrogenous albuminoids found in the wood which are subject to rot, and therefore the first object of wood preservation consists to remove these albuminoids or make them incapable of supporting rot. To do this, the impregnation process itself is preceded by another process, namely, the steaming, in which the ties are exposed in large iron cylinders for a few hours to the influence of steaming, whereby a part of the albuminoids are leached out and the remaining part coagulated. The albumen, easily soluble in warm water, has the property of becoming insoluble with high temperature, even below the boiling point of water, i. e., to coagulate, whereby it also loses the capacity of easily rotting.

Hence the opinion has existed that the ties need only be thoroughly steamed. Experience, however, has not furnished satisfactory basis for this opinion. The timbers which are only steamed do not resist the rot any longer than those which have not been operated upon.

This is easily explained by the observation that albumen, coagulated by heat, returns, under the influence of moisture and air, with time again into the condition in which it does not resist rot. It is here that the real impregnation becomes of importance. Several chemical materials, among which the chloride of zinc takes a prominent place, have the property in contact with the substances liable to rot to preserve the same from rotting. The best known chemical in this respect is the creosote, small quantities of which are found to conserve meat and to protect this substance, rich in albumen, for a long time against rot.

If wooden ties, after being dried and steamed, are impregnated with creosote or chloride of zinc, and these substances come into contact with the material capable of supporting rot, especially the albumens coagulated by the steam, they preserve these against decomposition reliably, so long as any antiseptic substances remain in the wood.

Since the chloride of zinc is a salt easily soluble in water and does not enter into an insoluable compound with the wood fiber, it must result that the ties impregnated with this substance, if left to lie in moist soil exposed to changes of weather, are leached out gradually and become poor in chloride of zinc, until finally all chloride of zinc is washed out.

From this time on the coagulated albumen ceases to resist rot, and gradually the decomposition attacks the wood fiber, and the ties lose their solidity.

The chemical analyses of the pieces submitted by the railroad company, namely, one freshly impregnated tie and one which has been lying in the ground for five years, showed the following results:

(1) The freshly impregnated tie did not contain chloride of zinc at the core or in the parts surrounding the same. As the examination progresses outward, and the narrower the rings become, the richer is the wood in that salt.

(2). From the piece of the tie which had been laid five years the chloride of zinc is almost entirely washed out, only on the outside quite small quantities may still be found.

From these observations and other experiences with ties impregnated with chloride of zinc, and not impregnated, I have come to the conviction that the impregnating of pine ties, which are here in question, if the wood is otherwise of normal condition, essentially increases the durability, and I do not think that I am in error if I state that the normal pine ties impregnated with chloride of zinc resist the rot much longer than such ties not impregnated, and just so much longer as the time during which still a part of the chloride of zinc is retained by them. When this is washed out the albumen in the wood begins gradually to rot and to communicate this process of disintegration to the wood fiber just as much as in the nonimpregnated tie, in which only the decomposition takes place from the start.

That in impregnating pine wood the liquid does not reach the core of the tie is due partly to its greater density, partly to its contents in resinous matters, which resist the penetrations of watery solutions.

On the ground of these observations, I believe that the question whether wood impregnation is of use and scientifically demonstrable should be answered in the affirmative.

Finally, I take the liberty of proposing a new plan for the better preservation of wood by the process of impregnation, namely, to the effect that there might be added to the chloride of zinc solution, which by necessity is always very weak, some raw carbolic acid, a substance not very soluble in water, but only so much of it as the chloride of zinc solution is capable of taking up. This addition would increase the cost of impregnation only very inconsiderably. The antiseptic effects of the carbolic acid (creosote) being decidedly greater than of the chloride of zinc, and the former being very much less soluble in water than chloride of zinc, it is to be expected that by the addition of carbolic acid the rotting in the wood containing it would be impeded longer than without the same.

LEIPSIC, April 17, 1872.

OPINION OF PROF. HLASIWETZ, OF THE POLYTECHNICAL INSTITUTE, VIENNA.

In response to the request of Mr. Guido Ruetgers to give an opinion whether impregnation of railway ties with the solution of chloride of zinc and an addition of a certain quantity of carbolic acid be a rational procedure, I do not hesitate to declare that with such a mixture, in a properly conducted process, the object of retarding the rotting of wood can be assuredly accomplished, since both substances belong to the most effective substances which we know and have long used for the purpose.

The chloride of zinc for impregnation of wood (Burnett's method, 1838) has proved itself satisfactory not only in general, but is preferred, on account of its great success almost everywhere, to the copper-sulphate and chloride of mercury.

Not less satisfactory from theoretical reasons is the impregnation with those tar oils, the main ingredient of which is the carbolic acid, and this method for conserving wood has lately also been widely used.

A combination of these two methods, based upon the fact that carbolic acid is soluble in considerable quantities in a chloride of zinc solution is therefore a happy thought, for thereby the impregnation fluid can be made to penetrate more easily into the interior, because with the addition of carbolic acid it has the capacity in a degree to dissolve the resinous contents of the wood. This can not be accomplished with the pure solution of chloride of zinc, and it may also be expected that such a mixture will enter with the protein substances of the wood into more insoluble, or either more rot-resisting compounds, than the chloride of zinc solution alone.

There is an additional advantage in the fact that with this mixture the process can be worked in the same manner as with the chloride of zinc solution alone; that is, to impregnate the wood after the larger part of the protein substances has been removed by steaming.

If tar oils alone are used, the removal of this part of the rot-producing substances can not be accomplished, since the wood, after this process, must be prepared, not by steaming, but by drying.

From these considerations I believe that in this proposed combination there is a thoroughly rational process, which may be recommended, and has before this been discussed with commendation by various others.

VIENNA, 1872.

In addition to the above it may also be of interest to reproduce the following table, kindly submitted by Mr. Holbein, showing the manner in which the cost of ties is figured and compared by the Ruetgers impregnation works.

Kind of tie (8.85 feet long).	Cost per tie for—							Total cost per tie in road-bed.	Estimated life of ties.	Annual charge at 4 per cent interest.
	The tie in the rough.	Impregnation with—			Planing (to give the slant of 1:20).	Transportation on railroad after impregnation.	Placing in road-bed.			
		Chloride of zinc.	Chloride of zinc, with addition of carbolic acid tar oil.	Tar oil.						
Pine:									Years.	
Untreated	$0.547	......	......	......	$0.0095	$0.0618	$0.0952	$0.714	8	$0.102
Impregnated with chloride of zinc with addition of tar oil	.547	......	$0.19	......	.0095	.0618	.0952	.733	11	.0999
	.547	......	.19	......	.0095	.0618	.0952	.733	12	.0928
	.547	......	.19	......	.0095	.0618	.0952	.733	15	.0885
Impregnated with tar oil	.547	......	......	$0.476	.0095	.0618	.0952	1.19	15	.102
	.547	......	......	.476	.0095	.0618	.0952	1.19	22	.0885
Oak:										
Untreated	1.142	......	......	......	.0119	.0714	.1071	1.333	13	.1285
Impregnated with chloride of zinc and tar oil	1.142	......	.16	......	.0119	.0714	.1071	1.49	15	.1285
Impregnated with tar oil	1.142	......	......	.286	.0119	.0714	.1071	1.62	17	.1285
	1.142	......	......	.286	.0119	.0714	.1071	1.62	20	.114
	1.142	......	......	.286	.0119	.0714	.1071	1.62	25	.0976

APPENDIX 2.

PATENTS RELATING TO METAL RAILWAY TRACKS.

By E. E. Russell Tratman, C. E.

In my original report was given a list of nearly 500 United States patents relating to metal railway tracks, beginning with July 26, 1839, and ending with March 18, 1890. Herewith is given a supplementary list of 250 patents, bringing the record up to March, 1894, and making a total of about 750 patents. Some comments upon the patents have already been given under the heading of "United States" in Part I. The list forms a descriptive index, giving a general idea of the design in each case, and enabling persons interested to find the specifications.

No. 423929; date, March 25, 1890; Fred J. Hoyt, Chicago, Ill.: A combination tie formed of a sheet three-eighths to five-eighths inch thick, 8 inches wide at the middle, and 20 inches at the ends. The middle arched upward, and the sides at the ends bent up to form boxes to receive wooden blocks secured by bolts across the tie.

No. 424793; date, April 1, 1890; Abraham Kimber, Indianapolis, Ind.: The tie is a hollow beam with recess for rail seat, the outer side of rail being secured by a keyed clamp (No. 434600).

No. 425266; date, April 8, 1890; Samuel D. Stauffer, Marietta, Pa.: The tie consists of two metal plates side by side, or one above the other, and separated by two spacing blocks, to which the rails are spiked. The two plates are hinged together at one end and secured by a bolt at the other end.

No. 425747; date, April 15, 1890; Orvill W. Brown, Hoyts Corners, N. Y.: The tie is a hollow box with flat bottom, semicircular upper part and rounded corners. The metal is cut away at the rail seats to let the rails rest on rectangular wooden blocks inside the tie. The rails are spiked to these blocks through holes in the tie.

No. 425937; date, April 15, 1890; John M. Fennerty, Washington, D. C.: An auxiliary metal tie laid upon the wooden ties at rail joints. The rails fit against outer lugs supporting the base and web, and an angle bar on the inside is secured by a wedge plate. One bolt passes through bar, rail, and lug.

No. 42605 and No. 426052; date, April 22, 1890; Moses W. Oliver, Lawrence, Mass.: A continuous longitudinal resting on the ties and having a wavy upper surface supporting the rail only between the ties.

No. 426458; date, April 29, 1890; George E. Marvin, Boston, Mass.: To the sides of a flat plate on edge (or a bar of ⊥ section) are bolted the flanges of rectangular boxes, forming two boxes at each rail seat to be filled with wood or other material. The top of the plate or bar is notched to receive the rail base. Blocks bolted against the middle of the tie to serve as anchors to resist lateral motion.

No. 426637; date, April 29, 1890; Theodore R. Dunning, Middletown, N. Y.: The tie is made from a steel sheet bent to form a box of triangular section, with apex downward, and having large holes cut in the sides to reduce the quantity of metal. The rail spikes pass through holes in the top and side of tie and have notched faces to engage with the edge of hole in the side. (No. 450739.)

No. 426877; date, April 29, 1890; G. L. Stream, New Orleans, La.: Portable railway track for sugar plantations, with flat-plate ties. The ends of the rail webs are mortised together.

No. 427109; date, May 6, 1890; James W. Price, Philadelphia, Pa.: A street railway track consisting of a shallow channel, longitudinal, supporting a longitudinal composed of a steel plate bent to form a series of troughs with flat tops and inclined sides. The vertical legs of the rail straddle this longitudinal and tie rods are passed through the flanges, shallow ⊥ cross-ties maintaining the gauge (*see* Price tie). (Nos. 430190, 431172, 462062, 467432, 503253, 504540.)

No. 427384; date, May 6, 1890; Lewis Wallace, Crawfordsville, Ind.: A flat bar, slightly curved in cross section, with enlarged ends carrying vertical jaws, between which are placed a block of wood, a rubber cushion, and a metal tie plate. Lugs on the inner top edges of the jaws fit over the rail flange.

No. 428869; date, May 27, 1890; James P. Taylor, Fort Worth, Tex.: The tie is a wrought-iron plate, bent into Λ form, with the rounded apex cut away at the rail seats and end, the rail resting on a jaw or clamp threaded upon a screw lying in the apex of the tie. By turning the rod the jaws, holding the inner flanges of the rails, force the rails against the sides of the secured rail seat.

No. 429436; date, June 3, 1890; H. L. Gillette, Buffalo, N. Y.: The rails rest on longitudinal plates 10 feet long with 1 foot between the ends. At intervals the plates are supported by metal columns resting upon deeply embedded cross-ties.

No. 429607; date, June 10, 1890; Charles Delorme and Emile Brochon, Troyes, France: The tie is of inverted channel section, with vertical sides. The rails are secured by lugs attached by bolts passing through the top table of tie and a separate bottom plate (with a key between rail and inner lug); or by spikes driven into wooden blocks inside the tie and held up by bolts.

No. 429613; date, June 10, 1890; Samson Fox, Leeds, England: Each rail is carried by a corrugated or wavy longitudinal, the curved ridges of which have ⊢⊣ shaped holes to admit the rail base and grip the web.

No. 430039; date, June 10, 1890; Patrick Rafferty, Ovid, N. Y.: The tie is composed of two blocks of wood, glass, iron, etc., 30 inches long, 12 inches thick, 12 and 14 inches wide at top and bottom. The inner end of each is held by an inner fork through the stem of which is passed a bolt, the two bolts engaging with a turnbuckle in the middle of the track.

No. 430197; date, June 17, 1890; James Richardson, Tarrytown, N. Y.: The webs or flanges of T rails rest in the top slots of longitudinal tubes of elliptical section, formed of steel plates, the tubes being filled with sand or concrete, etc. Top and bottom transverse tie rods connect the tubes and rails.

No. 430553; date, June 17, 1890; J. W. White, Widnes, England: A cross-tie of V section, with horrizontal top flanges, to which are bolted angle bars or clamps. (*See* England.)

No. 430590; date, June 17, 1890; James M. Price, Philadelphia, Pa.: This resembles No. 427109, but the bottom plates are flat, and ordinary rails rest on top of the longitudinals and are secured by bolted clamps on the ends of flat tie bars, the bars passing inside the troughs and having the ends bent round to hold the rail base, while the bolt passes through the rail, trough, and tie bar.

No. 430780; date, June 24, 1890; H. W. Libbey, Boston, Mass.: The wooden stringers of street railways carry cast-iron chairs connected by a casting of ⊥ section. The jaws of the chairs receive the webs of flangeless T rails which are bolted through them.

No. 431172; date, July 1, 1890; James M. Price, Philadelphia, Pa.: This resembles No. 430590; but no flat longitudinal is used, and flat cross-ties of different sections are laid across the trough longitudinals, resting upon the tops of the troughs. The rails are secured by clamps and vertical bolts.

No. 431839; date, July 8, 1890; William Bussard, Port Jefferson, Ohio: The tie has a flat base with three ribs along it. These ribs are notched to receive the rails, which are secured by keys driven between the rail and edge of notch. The ties are of cast metal.

No. 433524; date, August 5, 1890; Thomas W. Gilmer, Big Stone Gap, Va.: A trough tie, with slightly flaring sides and ends, and bolted clamp fastenings with vertical bolts.

No. 433651; date, August 5, 1890; F. F. Field and John Driscoll, Providence, R. I.: A cast-iron tie of rectangular box section, with riveted and bolted clamp fastenings, wooden blocks under the rails, and anchor plates riveted under the ends.

No. 433788; date, August 5, 1890; J. M. Fellows, Burlington, Ind.: The tie is formed of two forked pieces in plan, the forked ends carrying the rail clamps, and the ends of the shanks being connected by springs.

No. 433803; date, August 5, 1890; Stewart J. Morse, St. James, La.: The rails rest upon longitudinals, each composed of two angle irons, with the upright legs inclined together, and narrow horizontal flanges. The rails rest on bolted seats, and the longitudinals are connected by flat tiebars.

No. 434213; date, August 12, 1890; Hiram Taylor, of Northampton, and D. E. Sherman, of Springfield, Mass.: A sheet-iron or steel open trough tie, with flat bottom and sides flaring inward from the bottom. Two channel-shaped saddle pieces riveted inside form the rail seats, and each rail is held by four clamps bolted or riveted on the outside. The saddle pieces may straddle the top of the tie, and have one side bent to form a lug to hold the rail.

No. 434600; date, August 19, 1890; Abraham Kimber, Indianapolis, Ind.: A tie of curved trough section, with the edges notched to form rail seats, and inner flange of rail held by a clamp having lower end passing through bottom of the tie, the clamp being held in position by a horizontal key driven through holes in the sides of the tie.

No. 434848; date, August 19, 1890; John E. Taylor, Chester, Pa.: The tie is of ⊥ section, with the ends resting on angle-iron longitudinal pieces, having the vertical flanges on the outside. To the vertical web of the tie are riveted two angle irons, each forming a rail seat, the outer side of the seat being bent to embrace the rail flange, while the inner side of the flange is held by a loose stud.

No. 435004; date, August 26, 1890; Robert Whiteford, Louisville, Ky.: A flat casting, with enlarged ends, having 3-sided boxes, into which wooden blocks are fitted. Vertical flanges under the tie prevent lateral motion.

No. 435162; date, August 26, 1890; David Vanaman, Birdsboro, Pa.: The tie is of trough section, with flat bottom and vertical sides, portions of the bottom being punched out and bent down. Under each rail is a wooden block covered with an iron saddle. The rails are fastened by clamps of ┐ shape, with a bolt through the wooden block, or a vertical bolt through a flange on each clamp resting on the bottom of the tie. At joints the clamps form splice plates.

No. 435221; date, August 26, 1890; Marion M. Green, County Line, Tenn.: The tie is of H section, with a high block of I shape bolted to each end, and angle jaws or clamps to hold the rails bolted on top of these blocks.

No. 435768; date, September 2, 1890; William H. Pope, Fernandina, Fla.: The cross-ties are of angle shape ┌, supporting at each end a longitudinal plate, the middle of which is bent in channel form to receive the rail flange, and the outer edge is bent down to fit against the ends of the ties. Flat clamp plates resting on the longitudinal end rail are secured by vertical bolts.

No. 435806; date, September 2, 1890; Walter H. Dutton, East Bethany, N. Y.: The tie is composed of two plates on edge, placed together at the ends and middle, and bent so as to form hexagonal boxes at the rail seats. The boxes are closed at the bottom. The edges of the boxes are notched for the rails, the inner edges of notches fitting over the rail flange, and two outer clamps to each rail being used. The clamps straddle the side of box and are held by vertical bolts, with head under the bottom of box.

No. 437301; date, September 30, 1890; Frank G. Johnson, New York, N. Y.: Bolted rail clamp for steel tie, patented in 1886 (No. 354147). The clamp has a lug fitting in hole in tie, and a lug fitting in recess in top of rail flange, and is secured by a vertical bolt through top of tie, the purpose being to prevent creeping of rails.

No. 437302; date, September 30, 1890; Frank R. Johnson, New York, N.Y.: Inverted channel tie ┌┐ with rail fastenings as in previous patent. The rail splice bars have vertical flanges cut away to fit the ties, and the horizontal flanges cut away for the rail clamps.

No. 437476; date, September 30, 1890; Maximilian F. Bonzano, Philadelphia, Pa.: A tie of inverted channel section, with bottom flanges and vertical or inclined sides. The top table is cut away and bent down at sides and middle. Each rail is held by U bolt with two clamps. (*See* Bonzano tie.)

No. 437812; date, October 7, 1890; Henry O. Cook (James M. Hicks, administrator of H. O. Cook, deceased): The tie is composed of two angle irons ┌ ┐, and at each rail seat two other angle irons are riveted across the tie, thus, ┘ └. with a wooden block between them. (*See* Hicks tie, original report.)

No. 438583; date, October 14, 1890; Martin Hubbell, Mount Kisco, N. Y.: The tie is of channel shape, with vertical sides, flat bottom (no bottom at middle of tie), and two vertical diaphragms at each rail seat. A hollow stool or seat is inserted in each box thus formed, to the top of which the rail is secured by bolted clamps, the bolt heads being inside the stool or under the bottom of tie. The underside of bottom of tie is corrugated to hold the ballast.

No. 438764; date, October 21, 1890; Arthur M. Kramer, Uniontown, Pa.: A cross-tie of rectangular box section, with top and bottom cut away at the middle, and loosened part of top bent downward. The tie is filled with ballast, and under each rail is a wooden block (the top of tie being cut away at the rail seats), the rails being held by channel clamps [passing through holes in top and bottom of tie.

No. 439352; date, October 28, 1890; Charles A. Harvey, New York, N. Y.: A rail fastening for metal cross-ties, consisting of clamps having bottom lugs fitting into holes in the ties, and a wedge or key driven between the clamp and top of rail flange.

No. 439174; date, October 28, 1890; Rufus Osborn, Tekonsha, Mo. Cross-ties of channel form └──┘ carry L-shaped longitudinals with wooden longitudinals, to which the rails are spiked, the ties to be laid in a bed of cinders and tar. (No. 470700.)

No. 439482; date, October 28, 1890; Hiram D. Dasher, Middletown, Pa.: A tie of box form, with outer flange of rail held by lugs and inner flange by jaws on the end of a long arm, whose other end rests against the inclined face of a rib across the middle of the tie. (No. 491041.)

No. 440465; date, November 11, 1890; Joseph J. Callahan, Newburg, N. Y.: A cross-tie composed of two plates, with interlocking notches at the upper edges, the plates being inclined together in Λ shape. The apex is notched for the rail base. (*See* Callahan tie.)

No. 440653; date, November 18, 1890; John Reifert, Rome, N. Y.: An open, shallow channel tie, with horizontal top flanges, and the bottom bent down at the ends. A thin metal plate covers the top. The rails rest on the flanges and are secured to them by clamps of ┌ shape, as long as the width of tie. The clamps of each rail are held by two U bolts, with the horizontal legs lying under the flanges of the tie.

No. 440997; date, November 18, 1890; Charles H. Ewing and Charles G. Bockus, Philadelphia, Pa.: The tie consists of four shallow inverted channel pieces forming the ends of an X. The inner edges are connected by riveted straps, and there are two transverse tiebars (flat at the ends and on edge at the middle) passing through holes near the tops of the channels. The rails are held by clamps, with bolts inclined about 35 degrees outward from the rail, beveled washers being placed between the boltheads and underside of the bar. The bolts pass through the bar and channel.

No. 441416; date, November 25, 1890; C. B. Hutchins, Detroit, Mich.: Bridle rods to prevent spreading of rails. Each rod is a flat strap, with end bent up to fit the rail flange, and spike holes for inner side of rail. The inner ends of the straps hook together horizontally, and are secured to the wooden tie by lag screws.

No. 441549; date, November 25, 1890; Michael A. Glynn, Havana, Cuba: The tie is in sections like a +, with the top web cut away, and rail chairs or clamps bolted to the horizontal web.

No. 441784; date, December 2, 1890; Vernon A. Tyler, Morris Park, N. Y.: The tie consists of two shallow inverted channels, with the ends bent downward, these channels resting upon and riveted to a transverse T bar. The rail flanges are gripped by the split end of wedges which rest in holes in the tie, the jaw gripping the rail base and top of channel. Wooden cushions may be placed under the rails.

No. 441926; date, December 2, 1890; M. F. Bonzano, Philadelphia Pa.: A cross-tie composed of two angle, channel, or Z irons, with two flat or V-shaped plates riveted across the top, leaving the middle open. Rails secured by clamps and vertical hook bolts taking hold of bottom of tie or passing through holes in the sides. (No. 437476.) (*See* Bonzano tie.)

No. 442416; date, December 2, 1890; Edward Brandwood, Philadelphia, Pa.: A tie with section of +, having widened and deepened ends forming boxes in which are inserted the vertical legs of wedge clamps which form the rail seats, the weight of trains pressing the clamps down and spreading the lower ends so that the tops hug the rail flange. Modification of tie patented by Thomas W. Travis, July 30, 1878; No. 206647. (*See* Brandwood tie.)

No. 443594; date, December 30, 1890; William Godard and William Fiddler, Tonawanda, N. Y.: The rail rests upon a long metal tie plate, to which flat clamp plates are fastened by vertical countersunk bolts, with keys driven through slots in the bolts.

No. 443939; date, December 30, 1890; Thomas Foulds, Trevorton, Pa.: A tie composed of a flat plate resting on top of a corrugated plate having three longitudinal V-shaped ridges and longitudinal top flanges. The rails are held by hook bolts, with the nuts under the plate and flange.

No. 444439; date, January 13, 1891; John W. Hollin and Thomas B. Smith, New Richmond, Ind.: The tie is formed of two pieces placed side by side, each piece having one inner and one outer lug for the rails. They are halved together at the middle, and connected by three horizontal diagonal bolts.

No. 444909; date, January 20, 1891; William G. Sears, Chattanooga, Tenn.: The tie is of T section, and the rails are held by braces on the outside and studs on the inside, the braces and studs fitting into dovetailed holes in the tie.

No. 444910; date, January 20, 1891; William G. Sears, Chattanooga, Tenn: A trough tie, with flat bottom, sides flaring outward to the top and horizontal top flanges. At each rail seat is a plate across the tie, the ends bent to fit around the edges of the tie flanges and the middle plate curved upward to form an elastic seat for the rail.

No. 445274; date, January 27, 1891; Harry I. Jeffers, Lexington, Miss.: The tie is rectangular in plan. The rails rest on the ends of the tie, with the inner flange fitting into a recess. The outer flange is held by a lug on the end of a horizontal arm passing lengthwise through the end of the tie and secured by a vertical key at the hollow interior portion of tie.

No. 445325 and No 445326; date, January 27, 1891; David Y. Wilson, Gum Tree, Pa.: A flat or inverted channel tie, with rail clamps secured by vertical bolts. An elastic cushion is placed under the rail. The tie may be made of old rails. Creeping is prevented by a drift bolt driven through the tie into the ground.

No. 446405; date, February 10, 1891; E. D. De Clements, Detroit, Mich.: The tie is of inverted trough section, with the middle of top buckled or dished upward to stiffen it. The width increases from the ends to the middle. Each rail is held by two flat clamps and a U-bolt, the lower leg of bolt being curved, with a block between it and top of tie. At rail joints the clamps form part of the splice bars.

No. 446446 and No. 449117; date, February 17, 1891; T. Graham Gribble, Yonkers, N. Y.: A street-railway track consisting of a trough, or channel shaped longitudinal under each rail, with dovetailed lugs on the upper edges to fit the rails. Flat transverse T-bars are used. The longitudinals rest upon and are packed with concrete.

No. 446899 and No. 446900; date, February 24, 1891; Harlan P. Sweet, Los Angeles, Cal.: A cross tie of open curved trough section, with horizontal top flanges. A plate forming a rail seat is placed across the trough near each end and has a curved lower portion fitting the interior of the tie. The rails are secured by clamps bolted through the seat and tie flanges. (*See* Sweet tie.)

No. 447356; date, March 3, 1891; Eugene Robinson, Detroit, Mich.: Each tie consists of a flat plate, twisted so as to be vertical at the middle, where it is narrow. Each end is bent up angularly to this shape ┐, the rail resting on the flat portion and secured by an inner lug bearing against the upright face of tie and an outer lug passing through a hole in the top table. The latter clamp has a horizontal threaded end passing through the upright face of the tie and the inner clamp being secured by a nut.

No. 448005; date, March 10, 1891; Charles A. Beach, Albany, N. Y.: A street railway track with cross ties of channel section └┘, in which are I-shaped chairs, the tops of which are straddled by box girder rails ┌┐, secured by keys through the legs of rail and web of seat. The seats are bolted to the bottom of the tie. At joints the tie and seats are of extra width.

No. 450132; date, April 14, 1891; Ira L. Blakeslee, Kirkwood, N. Y.: The tie is corrugated, with almost six corrugations. The rails are secured by clamps the full width of tie, with bolts inclined about 40 degrees outward from the rails, the bolts passing through the clamps, ties, and lower washers. The lower surface of clamp and upper surface of washer are corrugated to fit the tie.

No. 450145; date, April 14, 1891; Elias Dietrich, Rochester, N. Y.: The tie has a flat plate, with a cross-shaped rib on the lower side, and to the top are secured four transverse plates, each pair inclined together and forming a box for block of wood wider at top than at bottom.

No. 450498; date, April 14, 1891; Ellison Saunders, Austin, Tex.: A flat tie, with raised ends through which passes a tie-rod. These ends have diagonal holes passing through top and sides into which are driven spikes, the ends of the spikes being clinched on the outside of the tie (No. 463456). (*See* Saunders tie.)

No. 450601; date, April 14, 1891; Hiram D. Dasher, Middletown, Pa.: The tie consists of an open channel, into which fits an inverted channel of slightly narrower width. The top of the latter is cut away at the rail seat, and bent to form rail clamps, the rail resting upon an interior block of wood. Horizontal keys are driven through the tie and blocks.

No. 450739; date, April 21, 1891; T. R. Dunning, Middletown, N. Y.: The tie consists of a flat plate, bent down at an angle of 45° at the ends and on each side of the rail seats, the middle portion being horizontal, but below the rail seats. An I beam passes through openings in the inclined faces, bearing on the under side of the seats and the top of the lower portion. The rails are secured by U lugs or clamps (No. 426637).

No. 451120; date, April 28, 1891; Leonard L. Frost, Barada, Nebr.: The ties are of ⊥ or + section, the upper and lower webs corrugated, and the former cut away for the rails.

No. 451295; date, April 28, 1891; Bridges Smith, Macon, Ga.: A sheet metal tie of rectangular box section, with dependent strips extending from the sides below the bottom. The rails are attached by bolts or otherwise, and the tie may be filled with ballast or utilized as a cross drain (No. 453922).

No. 451781; date, May 5, 1891; H. V. Slutz and T. Slutz, Atlanta, Ga.: A longitudinal under each rail is formed by a series of ⊔ and ⊓ channel pieces, with vertical flanges, the pieces being placed alternately, with the leg of one inside the next. The longitudinals are connected by flat tie bars, and the rails are secured by flat clamps bolted against the sides of the channel. Wooden filler blocks, or planks, may be placed inside the inverted channels, with the ends extending beyond the longitudinals so as to increase the bearing area (No. 492895).

No. 451804; date, May 5, 1891; Thomas Brown, Thurlow, Pa.: A cast-iron tie, with flat base plate, middle rib, and three-sided boxes at the ends to receive wooden blocks. The open ends of the boxes are closed by bolted plates to hold the blocks in.

No. 452333; date, May 12, 1891; Peter Bargion, San Francisco, Cal.: A street railway track, consisting of a continuous longitudinal bearing for a flangeless T rail.

No. 453099; date, May 26, 1891, George W. Young, Helena, Mont.: A cross tie composed of two angle irons bolted back to back ┐┌, the backs having curved grooves in which are driven spikes to hold the inner rail flanges, the outer flanges being held by fixed lugs.

No. 453721; date, June 9, 1891; David H. Southward, Coraopolis, Pa.: The tie is composed of two flat plates, narrowing toward the inner ends, which are turned and threaded and connected by a turn buckle or sleeve nut. A fixed jam to fit the inner flange and side of web of rail is bolted to each plate, the outer end of the plate being formed to fit the flange, web, and lead of rail.

No. 453886; date, June 9, 1891; Frank S. Ketchum, New York, N.Y.: A rail fastening for metal ties, consisting of clamps secured to lugs on top of the tie by horizontal bolts (No. 504066).

No. 453922; date, June 9, 1891; Bridges Smith, Macon, Ga.: Similar to No. 451295, but with a flat fastening plate inside the top of tie. A fold in the plate passes up through a slot in the tie and forms the outer lug for the rail, while the end passes through another slot and is bent round to hold the inner flange. The outer end of plate is bent up around the top of tie.

No. 454179; date, June 16, 1891; John J. Miller, Pittsburg, Pa.: A cast-iron tie with vertical ends, or standards, to which are attached chairs for the rails.

No. 455537; date, July 7, 1891; Joseph B. Morris, Chester, Pa.: The tie is of inverted channel section, with ribs on the bottom edges. The upper surface is formed to hold the inner flanges of rails, the outer flanges being held by clamps and springs.

No. 455885; date, July 14, 1891; G. H. Pond, Glens Falls, N. Y.: The tie is corrugated, forming a series of lengthwise troughs, with flat top and bottom and inclined sides, the open troughs being wider at top than at bottom. The gauge is maintained by projections on the tie, and the rails are held by small studs stamped up from the metal and hammered down on the rail flanges.

No. 456096; date, July 14, 1891; C. P. Howell, Chattanooga, Tenn.: The tie is a flat, shallow channel, with the ends turned up. Each rail rests upon two plates, the plate being bent back and forth upon itself to form a sort of spring, and the upper end forming the rail clamp. The outer plate buts against the end of the tie, while the inner one is set up by a horizontal screw working through a lug in the bottom of the tie. (No. 473071.)

No. 456343 and No. 456344; date, July 21, 1891; Albert E. Roberts, Norwalk, Ohio: Each tie is composed of two parts of L section, set back to back, but having the backs of irregular shape in plan, so as to interlock. Each part has a flat rail seat level with the top of web, and has one inside and one outside lug for the rails.

No. 457500, No. 457517, and No. 457518; date, August 11, 1891; Robert Morrell, Summit, N. J.: A cross-tie of channel section ⊔, with a wooden or other block under each rail. The blocks are not so deep as the tie, and the sides of the latter are therefore cut away at the rail seats, the outer edges of the notches being protected by a plate against the rail flange. The rails are fastened by inclined clamps, the lower end passing through the bottom of tie and the upper end resting upon the rail base (and also against the outside of rail web). Each clamp is held by a vertical hook bolt passing through the bottom of the tie. No. 457517 is similar, but with middle portion of bottom of tie cut away and bent down. No. 457518 has one U bolt instead of two hook bolts to each rail. (*See* Morrell tie.) (No. 483853.)

No. 457735; date, August 11, 1891; J. P. E. C. Stromeyer, London, England: The longitudinal is a plate formed in a series of hollow curved troughs separated by narrow ridges upon which the rails rest and upon which are formed lugs. The inner faces of the troughs have ribs at right angles to the rails. In each trough is driven a wooden block with inclined top face, forming the rail seat and forcing the rail against the lugs.

No. 459780; date, September 22, 1891; C. L. Gibbon and T. H. Gibbon, New York, N. Y.: The tie is a shallow inverted trough, and the rail fastenings resemble rail braces, with bottom lugs fitting into holes in the ties.

No. 460206; date, September 29, 1891; John P. Lancaster, Goshen, Ind.: The tie is an inverted channel, upon which are fastened two channel-shaped rail seats, with the open end toward the sides of the tie. The rails are secured by keyed clamps

No. 461261; date, October 13, 1891; John F. Harris, Fort Edward, N. Y.: The tie has two semicircular inverted troughs (or rectangular channels) connected by a flat strip ⌒_/⌒ to which two angle irons are riveted back to back. The tops of the angle irons are notched for the rail seats, and hinged rail clamps are secured between the angle irons by pins. (No. 466942.)

No. 461571; date, October 20, 1891; Alvan B. Fisher, Rutland, Mass.: The tie is an open channel ⊔, with plates riveted inside near the ends to form boxes for wooden blocks to which the rails are spiked. Angle iron brackets are riveted to the sides of the channel on the outside to prevent lateral motion.

No. 461775; date, October 20, 1891; Enoch L. Taylor, Philadelphia, Pa.: The tie is a shallow inverted channel with lugs stamped up for the outer rail fastenings, and clamps with horizontal hook bolts for the inner fastenings. A slot is cut in the middle of the tie, through which a ∩-shaped staple or anchor is driven into the ground. (Nos. 524359 and 525927.)

No. 462062; date, October 27, 1891; James M. Price, Philadelphia, Pa.: Flat (or shallow inverted channel) cross-ties bent down at the ends and then horizontally. The rails are fastened to the ties by clamps and vertical bolts. The ties may be connected by plate longitudinals bent to form a series of troughs. (Nos. 427109, 430590, and 431172.)

No. 462717; date, November 10, 1891; James H. Lynch, Addison, N. Y.: The tie is an open channel ⊔, with three cylindrical bars across the top at each seat, these bars supportnig the rails, which are secured by clamps of ∩ shape straddling the tie and fastened by keys.

No. 462900; date, November 10, 1891; William P. Hall, Piqua, Ohio: The tie is an inverted trough with convex sides, the lower edges of which are bent up in the form of gutters. The rail clamps are held by bolts of └┬┘ shape, the lower leg being a loop, to get a hold in the ballast.

No. 463045 and No. 463046; date, November 10, 1891; Charles P. Hammond, Birmingham, Ala.: A shallow inverted channel tie, with inclined sides. The rails are held by lugs or clamps fitting into holes in the tie and secured by taper keys. The middle part of the top is cut away and the ends of the opening turned down. (*See* Hammond tie.)

No. 463456; date, November 17, 1891; Ellison Saunders, Austin, Tex.: A flat tie with two blocks for rail seats connected by a tie-rod. The rail-seat blocks have curved spike holes into which spikes are driven, and so bent that they will not work loose. (No. 450498.)

No. 464054; date, December 1, 1891; Jacob C. Wolfe, New York, N. Y.: The ties are of cast iron, of rectangular section, with large holes in the sides and ends, and having several transverse diaphragms, also pierced with holes. The rails are bolted to flat seats, each supported by one of the diaphragms.

No. 464309; date, December 1, 1891; William B. Teall, Mason, Mich.: The tie is composed of two angles, irons back to back ⏋⎾, one end of each top table being turned down to form a closed end. A tie plate, with lugs at two diagonally opposite corners, is placed between the rail and tie, swung around to bring the lugs over the rail flange, and then bolted to the top table.

No. 464424; date, December 1, 1891; Albert G. Budington, Austin, Tex.: The tie is approximately I section with a base broader than the head. The head is recessed to receive the rail and grip the outer flange, the inner flange being held by a dovetailed clamp let into the head and secured by a bolt. (No. 479625 and No. 517915.)

No. 464552; date, December 8, 1891; John A. Carl, Bridgeport, Pa.: A box-shaped tie, narrower at top than at bottom, with two ribs on the center line inside, each rib being a curved top touching the underside of top table under the rail seat. The middle of top table is cut away. The rails are spiked to filler blocks inside the tie, two for each rail.

No. 465263; date, December 15, 1891; J. W. Hardy and W. O. L. Jewett, Shelbina, Mo.: A tie of ┌┬┐ section with grooves for the rails, and a longitudinal groove between these, in which slide clamp plates to hold the inner flanges of rails.

No. 465874; date, December 29, 1891; John Moser and Ernest Moeckel, Ashland, Wis.: The tie is a shallow T iron, curved upward between the rail seats. To each rail seat is riveted a rectangular box, in which is a block of wood, rubber, etc. The outer flange of rail is held by a T headed spike driven into the block (the back of spike bearing against the side of the box), while the inner flange is held by a clamp screwed through the top of the side of the box.

No. 466168; date, December 29, 1891; Francis H. Hicks, Little Rock, Ark.: The tie is formed of two sheet-steel angles the full length of the tie, the horizontal edges overlapping, and the vertical sides having narrow horizontal flanges ┌──┐. Each piece has one inside and one outside rail lug, and the two pieces are brought together by two horizontal bolts.

No. 466218; date, December 29, 1891; Theodore S. Brooks, Garrison, N. Y.: The tie is a stamped or dished plate, with two bolted clamps to each rail, the rail resting upon the horizontal parts of the clamps. The bolts are inclined outward from the vertical.

No. 466942; date, January 12, 1892; John F. Harris, Fort Edward, N. Y.: A tie of open channel section └─┘ pressed up from a blank. The top edges are notched for the rails, which are spiked to wooden blocks held in place by two horizontal bolts to each block. (No. 461261.)

No. 467166; date, January 19, 1892; A. J. Hartford, New York, N. Y.: The tie is an open channel, with reinforced top edges └──┘, and has the edges notched to fit over both rail flanges, an inclined slot from the lower inner edge of each notch allowing the rail to be slipped in until the outer flange passes into the notch. The rail rests on a wooden or other cushion block fitted into a channel-shaped box resting inside the tie. (No. 478058 and No. 487733.)

No. 467432; date, January 19, 1892; James M. Price, Philadelphia, Pa.: Each rail rests intermittently on a longitudinal of shallow inverted trough or channel section, bent to form a series of troughs, to the tops of which the rails are secured by bolts and clamps. At intervals the top of the troughs rest upon saddles having inclined sides and horizontal bottom flanges at right angles to the rails, the saddles being connected by the rods. (No. 427109.)

No. 467790; date, January 26, 1892; Joseph J. Crane, Summertown, Tenn.: A cross-tie of ⊥ section, with flat rail seats on the top of the web, supported by brackets or webs under the line of rail. Fixed lugs are on the outside and bolted clamps on the inside of the rails. (*See* Crane tie.)

No. 468360; date, February 9, 1892; Charles F. Nelson, Winchester, Va.: The tie is of ⊥ or △ section, but with concave sides. The top is notched for rail seats, and each rail has the inner flange held by two hook bolts whose nuts bear against the ends of a plate fitting into a hole in the tie nearly under the outer edge of rail.

No. 470094; date, March 1, 1892; Thomas C. Anderson, Moscow, N. Y.: The tie is composed of two channels, the lower one open, the upper one (slightly narrower) inverted and fitting into the lower one. The rails are fastened to the top table of the upper channel by lugs and bolted clamps.

No. 470585; date, March 8, 1892; E. S. Moffat and T. G. Wolf, Scranton, Pa.: The tie is made of old track rails inverted, with rail chains or clamps bolted to the flanges. It may be made of two parallel rails bolted together, of one rail with an extra piece at each end to give increased width, or two pieces at each end, with a connecting tie bar. (No. 472901.)

No. 470641; date, March 8, 1892; Richard W. King, Wichita, Kans.: Shallow trough longitudinals are used, with flat tops and curved sides. At intervals the longitudinals are recessed to receive the saddle ends of tie rods, the saddle carrying the inner logs of rail fastenings and having outer clamps bolted through saddle and longitudinals. (No. 499925.)

No. 470700; date, March 15, 1892; Rufus Osborne, Tekonsha, Mich.: Metal longitudinal angles ⊥ ⊥ hold wooden longitudinals, and these are crossed at intervals by cross-ties of similar section but with the vertical webs closer together. (No. 439174.)

No. 470795; date, March 15, 1892; George W. Stevenson, Reading, Pa.: The tie is of box shape, with the top cut away at the middle to receive heavy clamp plates whose ends abut against a central bar. The rails rest on wood blocks inserted in the ends of the ties.

No. 470904; date, March 15, 1892; Ambrose W. Straub, Philadelphia, Pa.: The longitudinals are shallow, with flaring sides turned up at the edges like gutters, a central rib underneath and an upper rib on the outside of the rail seat. The inner flanges of rails are held by bolted clamps. At intervals the longitudinals rest on inverted channel cross-ties, with curved top table and one side deeper than the other.

No. 471582; date, March 29, 1892; A. G. E. Westmacott and J. P. Hutchinson, Newtown, Pa.: The ties are in section like the hull of a boat, the top table cut away at the middle and bent over the ends. The rails are fastened by spikes or studs. No. 471583 is similar, but the ties are of inverted trough section, wider at the bottom and having horizontal bottom flanges.

No. 472034; date, April 5, 1892; John Conley, Denver, Colo.: This is a patent rail fastening consisting of a metal rod, part of which is coiled spirally. It lies within the tie and has one end hooked over the inner rail flange and the other over the end of the tie.

No. 472901; date, April 12, 1892; E. S. Moffat and T. G. Wolf, Scranton, Pa.: The tie is an old rail, head uppermost, with chairs fitting over the head and riveted or bolted to the web. Bolted and riveted rail clamps are on top of the chair. (No. 470585.)

No. 473071; date, April 19, 1892; C. P. Howell, Chattanooga, Tenn.: The tie is a shallow channel with closed ends, and the top table at the ends bent to fit the outer flange and web of the rail. The inner flange is held by a similar clamp with block under the rail, a horizontal bolt passing through the clamp and end of tie. (No. 456096.)

No. 473934; date, May 3, 1892; Orville W. Knox, Oneida, N. Y.: The ties are of T section with cross ribs at middle and ends, and the rails are secured by large flat bolted clamp plates. (No. 462716.)

No. 473999; date, May 3, 1892; Hiram Daily, Lancaster, Pa.: The tie is of semicylindrical section with flat part on bottom. Bolted jaws secure the rails.

No. 474216; date, May 3, 1892; Robert J. Colvin, Lancaster, Pa.: The cross-ties are of ⊥ section with curved bottom flanges, and between the ties are longitudinal bearings of I section, with ends sloped to fit the contour of tie. The rails are secured by spikes or studs.

No. 474873; date, May 17, 1892; Alexander Story, Washington, Iowa.: The tie is composed of two pieces side by side, each carrying one inner and one outer rail lug. The pieces are secured together by a tape horizontal key. Each piece is of inverted channel section with heavy ribs across the channel.

No. 474877; date, May 17, 1892; Ezekiel F. Taylor, Washington, Ky.: The ties are rectangular bars laid diagonally across the track and forming a continuous W. The ends are shaped to fit into triangular shoes.

No. 475981; date, May. 31, 1892; Frank S. Ketchum, New York, N. Y.: A shallow inverted channel tie, has a hollow rib stamped up along the mid-line of top table, the rib being cut away at the rail seats.

No. 475999; date, May 31, 1892; Frank A. Byram, Philadelphia, Pa.: The tie is formed from a flat blank of +—+ shape or plan, the side and end wings bent up to form three-sided boxes for wooden blocks. The middle portion is shaped to a ∧ section.

No. 476404; date, June 7, 1892; William McManes and George E. Lum, Summit, N.J.: The tie is an open channel, edges notched for rail seats, and a wooden block under end rail. The flat clamp plates have the back edges fitting in slots in the sides of the tie, and end clamp is held by an inclined hook bolt, not passing through the block.

No. 477112; date, June 14, 1892; William A. Graeber, Shenandoah, Pa.: The tie is of semicylindrical section, open at bottom, with a flat plate extending beyond the top ⌒, the rail clamp being bolted to the flanges. Another form of tie is of ∇ section with concaved sides.

No. 477679; date, June 28, 1892; Arthur J. Moxham, Johnstown, Pa.: The tie is an inverted channel with a ridge at end rail seat, to which ridge is welded the web of a flangeless T street rail. (No. 505988, 508038, 513712.)

No. 478058; date, June 28, 1892; Arthur J. Hartford, New York, N. Y.: A pressed steel tie of inverted channel section, of the general form shown on Plate No. 31, but with a recessed pocket on each side of end rail seat, the inclined bottom of pocket causing the bolts to incline outward from the rails. (No. 467166.)

No. 479,289; date, July 19, 1892; Henry A. Liddon, Brainerd, Minn.: The tie is of inverted channel section, with two outside lugs stamped up at each rail seat, and an inner clamp plate secured by a] shaped clamp gripping the plate rod tie.

No. 479625; date, July 26, 1892; Albert S. Budington, Austin, Tex.: A tie of approximately ⊥ or △ section, with upper part separate from lower. Rails secured by dovetailed and bolted clamps. (No. 464424.)

No. 479808; Thomas W. Hutchins, Wyoming, Pa.: A tie formed of blocks of concrete, burnt clay, etc., held together by a tie-rod.

No. 482967; date, September 20, 1892; Charles B. Macneal, Philadelphia, Pa.: A tie composed of an old track rail, with the head cut away to form a lug for inner flange of rail, and the ends bolted to cast chairs whose upper parts carry the outer lugs. (No. 503054.)

No. 482997; date, September 20, 1892; Robert E. Daniels, Youngstown, Ohio: A corrugated tie, to which the rails are fastened by V pieces, the upright lip being bent down upon the rail flanges. (*See* Daniels tie.) (No. 522974.)

No. 483518; date, October 4, 1892; Hugo Alexy, Budapest, Austria-Hungary: A fastening consisting of an outside gib, two inside gibs back to back (as in Pl. 13), with a vertical key between the latter. The key is broader at the base, and the top is threaded, the key being drawn up by a nut.

No. 483773; date, October 4, 1892; B. F. and M. F. Sparr, Brooklyn, N. Y.: A flat cross-tie, with ends curved down. The rail fastenings are a combination of fixed or riveted lugs and movable locking T clamps set up by circular taper bolts driven under the back of clamp. (No. 503442.)

No. 483821; date, October 4, 1892; Samuel H. Wilson, Webster, Mass.: This tie is similar to the Severac type. It is a high I beam, with a wide, flat base plate under each end extending a third of the length. On top are keyed two open channels, with the sides notched for the rails to rest on thin wooden cushions. The rails are secured by clamps and vertical bolts having the heads under the top flange of the I beam.

No. 483853, No. 483854, and No. 483855; date, October 4, 1894; Robert Morrell, Summit, N. J.: An open channel tie formed from a block having a rectangular opening in the bottom, the sides of which are bent downward. No. 483854 resembles the other Morrell ties, but an iron stool replaces the wooden block for the rail. No. 483855 is for a fastening consisting of two S clamps, one on each side of the wooden block. The top loop fits over the rail flange and the bottom loop under a bolt across the tie near the bottom. The clamps are held together by a horizontal bolt (No. 457500).

No. 484036; date, October 11, 1892; Thomas B. Moore, Philadelphia, Pa., and John T. Hodgson, Maywood, Ill.: The tie is of inverted channel section, with flaring sides, and the top table cut away at the middle. Each rail is held by two Γ clamps, the leg of which enters a hole in the tie. A vertical bolt and nut holds each clamp. A stud fitting a hole in the tie and a recess in the rail base prevent creeping.

No. 484855; date, October 25, 1892; William M. Hewitt, Chattanooga, Tenn.: A crossbar is bent up at the ends to make the rail seat above the middle of the bar, and the ends are formed into lugs to hold the outer rail flanges, the inner flange being held by a clamp and U bolt embracing the bar. A rectangular block of asphalt or vitrified clay, etc., at each end has an opening to receive the bar, and these blocks provide the necessary bearing area.

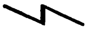
No. 485097; date, October 25, 1892; Thornton W. Fay, Philadelphia, Pa.: A flat plate, with ribs pressed up to hold the rail flanges; these to be spiked at intervals to the wooden ties.

No. 486077; date, November 15, 1892; Jerome M. Bordner, Palmyra, Pa.: A solid flat tie, with outside rail braces and inside flange clamps, both having lugs entering chambers in the tie and secured by a through bolt to each.

No. 486628; date, November 22, 1892; Joseph L. Chapman, Haddonfield, N. J.: A cast-iron tie of inverted channel section, with flaring sides wider at the bottom. The width is reduced at the middle. At each end is a raised hollow rail seat, under which fit the heads of the clamp bolts.

No. 486741; date, November 22, 1892; Thomas B. Smith, Bridgeport, Ohio: A flat plate, with enlarged ends having the sides bent up and cut to form lugs for the rail. It is to prevent spreading of the rails; and is spiked on top of the ordinary wooden tie.

No. 486959; date, November 29, 1892; George H. Sellers, Ridley Park, Pa.: An inverted channel tie, with fluted or corrugated sides and ends, and with rail seats pressed up from the top table. Angle bar clamps are used, the outer ones secured by two rivets and the inner ones by two bolts each. Liners between the web and inner clamp and web of rail allow for adjustment of gauge.

No. 487016; date, November 29, 1892; Louis A. Kenyon, Fairwater, Wis.: The tie has a flat rectangular base, with raised rail seats connected by a rib  shaped in plan. The outer flange of the rail is held by a cast lug, and the inner flange (or both flanges) by a pair of flat wedge-shaped spikes driven back to back into a hole sloping slightly under the rail.

No. 487351; date, December 6, 1892; Russell D. Price, Parkside, Pa.: The tie is of tubular section, with flattened bottom and the top bent down at the ends to form recessed rail seats. The flat rail clamps have semicylindrical back edges fitting into the edges of the recess.

No. 487642; date, December 6, 1892; Calvin M. Reed, Hoppenville, Pa.: A cross-tie of inverted trough section ⌒, cut out at the rail seats, the rails, being secured by wedges driven inside the top of tie and passing through the rail web.

No. 487733; date, December 13, 1892; Arthur J. Hartford, New York, N.Y.: A cross-tie of inverted channel section, with the ends bent down at an angle and then turned horizontal again. The outer flange of the rail is held by a stamped lug, the inner flange by a lug on a tie plate; an inner stamped lug bears against the back of the tie plate. (No. 467166 and No. 478058.)

No. 487952; date, December 13, 1892; Andreas Mattijetz, Giddings, Tex.: An open shallow channel tie, with two rail seats of inverted channels fitted inside the tie, and having four riveted clamps to each rail. The ends are closed by channel riveted inside the tie.

No. 488578; date, December 27, 1892; Samuel R. Scharf, Washington, D. C.: The tie is of inverted channel section, with the ends bent at an angle below the body so as to hold a core of ballast. One flange of the rail is held by a stamped or riveted lug. The other is held by a gib, with a bearing block at the back having a curved hole so that the lower end of a spike takes hold of the underside of the top table.

No. 488904; date, December 27, 1892; William W. Pitts, San Luis Potosi, Mexico: The tie is a narrow, deep, inverted, channel with horizontal bottom flanges __⊓__. The rail rests on a saddle piece on top of tie, and is secured by disk-shaped clamps having a notch in one side for the tie and rail flange, and at the opposite side for the tie. The horizontal flanges of the ties fit into the slotted ends of longitudinal braces.

No. 490586; date, January 24, 1893; Samuel McElfatrick, Princeton, Ky.: The section of the tie is ┌─┘ or ┼, with the upper web cut away at the rail seats, and theends of this web shaped to fit the outside of rail flange and web. An angle iron between the rails has its horizontal flange under the tie and the ends of its web formed to fit the inside of rail flange and web. It is secured to the web of the tie by a horizontal bolt. (No. 497678.)

No. 491041; date, January 31, 1893; Hiram D. Dasher, Middletown, Pa.: The tie is an open channel, with edges notched for the rail base and the rail resting on a wooden block. The top of the channel is covered at the ends, the end of the strip forming the outer lug for the rail. The inner flange of rail is held by an angle clamp 7 set up by a horizontal taper key driven through the tie against its back. (No. 439482.)

No. 491048; date, January 31, 1893; Charles A. Gildemeyer, Haddonfield, N. J.: The tie has two flat circular ends for rail seats, with arms butted or halved together at the middle and bolted or riveted. Each rail seat has a lug at one side and a vertical clamp bolted to the other side, the latter gripping both rail flanges.

No. 491206; date, February 7, 1893; William H. Brooks, West Point, N. Y.: A fastening consisting of a vertical hook bolt, with the vertical leg passing through the rail clamp and secured by a split pin.

No. 491229; date, February 7, 1893; Nathan M. Thomas, Aberdeen, Md.: A rectangular box tie, with each rail wedged between the ends of two long plates, the back of one plate bearing against the outer end of tie and that of the other against a middle rib across the tie.

No. 491441; date, February 7, 1893; Alfred H. Newpher, Pullman, Ill.: A device to prevent rail spreading. Each rail rests on two blocks, having lugs holding the flanges, and a tie-rod passes through the lower part of all four blocks and is secured by nuts.

No. 491922; date, February 14, 1893; T. J. Bronson and A. Armstrong, Jacksonville, Ill.: A semicylindrical tie, with horizontal bottom flanges and fixed inside lugs for the rails. The rail seats are saddle pieces and the outer lugs are bolted to the tie.

No. 492121; date, February 21, 1893; Ambrose W. Straub, Philadelphia, Pa.: A tie of └──┐ section, with a part of the horizontal table cut away and its edges bent up and down. At each rail seat are bolted two angle irons ──┘└──, with a wooden bearing block between, or having the tops formed to support and grip the rail flange. (*See* Straub tie.)

No. 492446; date, February 28, 1893; George Tarrant, Brandon, N. Y.: The tie is of + shape, with a vertical cylinder for each rail seat, in which is fitted a rubber block. The rail rests on a tie plate having two lugs for the rail, a lug at each end to bolt against the web of the tie, and a projecting disk below to fit into the tie cylinder.

No. 492895; date, March 7, 1893; H. V. Slutz, of Alta, and T. Slutz, of Storm Lake, Iowa: The longitudinal is similar to that of their patent, No. 451781, but the track is strengthened by occasional cross-ties of ┌─┐ section on curves, while, to allow for curvature, wedges or fillers are place between the overlapping vertical lugs of the channels forming the longitudinal on the inner side of the curve. (No. 451781.)

No. 493052; date, March 7, 1893; E. L. Arnold, Georgetown, Tex.: The cross-ties are of A section, with flattened top, having dovetailed recesses for the rails, which are secured by blocks or wedges, with grooves fitting the rail flanges. Between the tie is a box-shaped bearing piece under each rail, the ends of the boxes converted with the rail wedge seats.

No. 493492; date, March 14, 1893; C. L. Fitzhugh, of Allegheny, and S. S. Babbitt, of Pittsburg, Pa.: The tie is composed of two or three channels placed side by side, ┌─┐┌─┐┌─┐, each one having one end bent down below the level of the body, and having two rail lugs. They are fastened together by horizontal flat taper keys.

No. 493802; date, March 21, 1893; Wm. J. Williams, Pittsburg, Pa.: A rail joint for metal ties of open channel section, with the sides cut away to let the rail rest on the bottom. The edges of the notches are shaped to fit the back of the angle bars. One bar has a hook lug passing through the bottom of the tie. The other is set up by a flat, horizontal taper key driven through the sides of the channel.

No. 494029; date, March 21, 1893; Albert E. Roberts, Norwalk, Ohio: An open channel tie with metal stools or bearing blocks to which the rails are spiked. (No. 517302.)

No. 494314; date, March 28, 1893; Edwin D. Bangs, Milwaukee, Wis.: The tie is of inverted trough section, with widely flaring sides, and the top recessed for the rail base which is secured by flat clamps and vertical bolts.

No. 495146; date, April 11, 1893; W. W. Baird, Bloomington, Ill.: A street railway track consisting of cross-ties of flat bars, with two vertical loops at each end to hold the stringers, which are rabbeted for angle iron rails └── forming a side-bearing track. The ends of the ties rest on brick piers.

No. 496183; date, April 25, 1893; Auguste Ponsard, Paris, France: A rolled cross-tie of triple channel section, the middle channel open on top. Each rail rests on a riveted tie plate and is secured to a wooden block on a metal washer in the channel by lag screws or tapped studs, respectively. (*See* France, Part I.)

No. 496218; date, April 25, 1893; E. P. Caldwell and F. H. Heath, Minneapolis, Minn.: The ties are of inverted channel section with closed ends. At rail joints the rail ends rest on a bridge plate whose ends rest on the ties and whose lower web lies between them. Two channel bars ⊏ ⊐ hold the rail flange and bridge, and are held together by a bolt under the rail. This is the Heath rail joint.

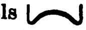
No. 497562; date, May 16, 1893; William S. Ward, Philadelphia, Pa.: The ties are of inverted channel section with two grooves to take the webs of flangeless T rails. The rail ends are scarfed for joints. (*See* Ward tie.)

No. 497678; date, May 16, 1893; Samuel McElfatrick, Princeton, Ky.: A tie composed of two ⊢ bars back to back, ⊣⊢; one has the upper web notched for rails and formed to grip outside of rails; the other has upper web only between the rails, with ends of web formed to grip the inside of rails. (No. 490586.)

No. 497954; date, May 23, 1893; Matthew Fitzgerald, Troy, N. Y.: The tie is of inverted channel section with ends cut and folded so as to be closed. Outside angle-bar clamps have vertical lugs below each end, with a bolt through the lugs and the tie.

No. 498883; date, June 6, 1893; E. M. Howard and T. J. Egan, Scranton, Pa.: A tie of approximately I section, having one outside and one inside rail lug, and a separate bar with the other lugs. The tie and bar have engaging teeth on the contact surfaces.

No. 499071; date, June 6, 1893; W. W. Whitaker, Gloversville, N. Y.: A tie of T section, with two raised bolted rail seats of channel form, but with S shaped sides. The rail rests on tie plates with lugs, the plates being shifted into position and then bolted to the rail seat.

No. 499077; date, June 6, 1893; Charles Warden, Rye, N. Y.: A tie of inverted trough section with exterior vertical sides forming two narrow open channels  the sides being higher than the trough and cut away for the rails. Grooved clamps straddle the tops of the sides and are fastened by horizontal bolts across the top of the tie and above the trough.

No. 499139; date, June 6, 1893; John Murnane, Coopersville, N. Y.: The tie is of solid rectangular section with vertical lugs, to which are bolted the turned up ends of tie plates, having lugs to hold the rails.

No. 499233; date, June 13, 1893; James P. Kimble, Rose Hill, Iowa: A device to prevent spreading of track. End rail has two angle-bar clamps with a bottom flange extending partly under base of rail, with a lug below this flange. The tie-rod passes through all four lugs and is fastened by nuts. An improvement upon No. 477943. Similar to No. 491441.

No. 499925; date, June 20, 1893; Richard W. King, Wichita, Kans.: The rails are bolted to longitudinals of shallow inverted trough section, with convex sides and horizontal bottom flanges, resting upon cross-ties of similar section. (No. 470641.)

No. 500266; date, June 27, 1893; Gustav Lindenthal, Pittsburg, Pa.: Cross-ties of high triangular section Δ with straight or concave sides riveted to bottom straps and a filler piece on top at each rail seat. The tie is filled with ballast and can be tamped through the opening along the apex. The filler pieces form rail seats to which the rails are bolted.

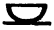
No. 500376; date, June 27, 1893; E. W. Bryant and Samuel Kinkerter, Ithaca, Mich.: A device to prevent spreading of rails. Each rail is held by two clamps embracing web and base, held together by a bolt under the rail. Two rods have their heads inside the inner clamps, and the threaded ends are connected by a turn-buckle.

No. 500473; date, June 27, 1893; Henry G. Davis, Everett, Mass.: A cast-iron tie, of inverted channel section, with outside lugs, and a pocket to hold the lower end of a clamp of] shape with a vertical key driven at its back.

No. 501678; date, July 18, 1893; Thomas H. Dahill, Alfred Center, N. Y.: A device to prevent spreading rails. Two flat, half-length plates have ends forming outer lugs for the rails. A third plate rests on these and has its ends resting on the inner flanges. Bolts pass through the three plates at the middle.

No. 502435, August 1, 1893; George P. Gunn, Ilion, N. Y.: The tie is a shallow inverted channel with one end of the top table turned up and a slot across the other end. It has also one inside and one outside rail lug and a middle lug. The ties are laid with the ends alternating, a rail clamp being set up by a key driven between the clamp and turned up end. Vertical anchor plates are driven through the slotted ends. A longitudinal locking bar is laid upon middle of the ties, the middle lugs being alternately on either side of it.

No. 502464; date August 1, 1893; John P. Lancaster, Cleveland, Ohio: An inverted channel tie with a W piece bolted inside under each rail seat. Gib fastenings secure the rails.

No. 502638 and No. 502638*a*; date, August 1, 1893; Horace B. Rowland, Philadelphia, Pa.: A tie of semicylindrical section with flat top and flat bottom flanges,  the latter cut away at the rail seats. The rails are fastened by clamps held by U straps encircling the tie, the upper ends of the strap having lugs and being connected by a horizontal bolt above the tie. No. 502639 is for a tie consisting of two concentric tubes, with openings to let the rails rest on wooden blocks, the edges of the openings formed as rail clamps. A bolt passes through the axis of the tie, with nuts on the outside of end caps closing the tie. (No. 505484.)

No. 502830; date, August 8, 1893; John L. Pope, Cleveland, Ohio: A tie of inverted channel section. At each rail seat are two plates with enlarged inner ends fitting a depression in the tie, and pins at these ends entering holes in the tie under the center line of rail. The rails are held by ⊐ gibs passing through the plates and tie, and held by cotters driven at their backs. (See Pope tie.)

No. 503054; date, August 8, 1893; Charles B. MacNeal, Philadelphia, Pa.: A tie of approximately ⊥ section with the web notched for rail, the edge of notch forming inner rail lug. The tie is straddled by two rail chains on which are the outside lugs or braces, and the chains are secured by keys through the tie. (No. 482967.)

No. 503184; date, August 15, 1893; Phillip Wheeler, Branchport, N. Y.: An open channel tie with two wooden blocks (one upon the other, with inclined faces) under each rail. Two clamps of └─ ─┘ shape bolted to the outside of the channel hold each rail.

No. 503253; date, August 15, 1893; James M. Price, Philadelphia, Pa.: A longitudinal of inverted channel section or ┌─┐┌─┐ section, with angle iron on top retaining wooden bearing blocks. (No. 427109.)

No. 503442; date, August 15, 1893; B. F. Sparr, and M. F. Sparr, Brooklyn, N. Y.: A rail fastening similar to No. 483773.

No. 504066 and No. 504067; date, August 29, 1893; Frank S. Ketchum, New York, N. Y.: A tie of inverted channel section with hollow semicylindrical rib on top. Top table cut away at the middle. Rib cut away at rail seats, and rail clamps have projections entering the rib and secured by transverse keys. (No. 453866.)

No. 504540; date, September 5, 1893; James M. Price, Philadelphia, Pa.: An open channel tie composed of two angle irons └─ ─┘, with a piece of T iron riveted under the middle and each rail seat. Angle irons inside the tie hold two wooden ─┘ └─ and the rails are held by channel clamps bearing upon flange of rail and of T iron, secured by a bolt through clamps and block. (No. 427108.)

No. 504695; date, September 5, 1893; Edward Siskron, Minneapolis, Minn.: A shallow open channel tie with convex bottom. At each rail seat is bolted a chair of channel form with concave sides parallel with tie. The rails are held by spikes with split keys through slots in spikes inside the tie.

No. 505019 and No. 505020; date, September 12, 1893; N. Benjamin, Elmira, N. Y.: A cross-tie of two T irons (⊥⊥) with a crosspiece of T iron under the bottom at each rail seat. In the channel is a T iron, parallel with tie, forming a rail seat to which the rails are secured by vertical spikes. No. 505020 has bolts instead of spikes, and the rail seat is a piece of inverted T rail with its head below the tie.

No. 505478; date, September 26, 1893; Esprit Perrody, Geneva, Switzerland: Under each rail is a shallow inverted metal box filled with tar concrete. The rails are secured by bolted clamps. Flat tie bars on edge connect the boxes.

No. 505484; date, September 26, 1893; Horace B. Rowland, Philadelphia, Pa.: Open channel tie. The outer clamps are on plates extending under the rails and vertical ends connected by a bolt. (No. 502638.)

No. 505988; date, October 3, 1893; Arthur J. Moxham, Johnstown, Pa.: A cross-tie of inverted channel section, with thickened rib inside top table, and form pressed lugs to engage base of girder rail or flanges of chairs for rails. (No. 477679.)

No. 507179; date, October 24, 1893; Charles E. Steiner, York, Pa.: A hollow rectangular tie, cut out at each end to receive the rail, the edges of notch fitting flange and web of inside of rail and a dovetailed block flush with the tie fitting the outer side of the rail.

No. 508038; date, November 7, 1893; Arthur J. Moxham, Johnstown, Pa.: Flat cross-ties, with longitudinal ribs on the underside, and the ends of the tie are forked in place and welded to the rails (No. 505988).

No. 508049; date, November 7, 1893; Francis P. Reilly, New York, N. Y.: A street railway cross-tie of inverted channel section, with the top table pressed up to form two vertical ribs at each rail seat, to which are riveted or welded the legs of channel-shaped chairs for girder rails.

No. 508243; date, November 7, 1893; Samuel Rideal, Manchester, England: The rails rest on flat rectangular plates of cast iron or steel, having lugs, with keys driven between the lug and rail. The plates are stiffened by ribs on the underside. The plates may all be placed lengthwise of the rail, and each pair connected by a tiebar; or pairs alternately parallel with and at right angles to the rails, the former pairs connected by tiebars. (*See* Sampan tie, England, in original report.)

No. 508575; date, November 14, 1893; David Markley, Lexington, Ohio: Rail braces consisting of two angle-iron plates, each having a flange passing round the end of the tie and a lug for the outer flange of the rail. The plates rest upon one of the upper corners of the tie and are held together by rods and a turn-buckle against the side of the tie.

No. 508664; date, November 14, 1893; Jasper P. Warner, Decatur, Mich.: The tie is an open double channel ⊥⊥⊥. The rails rest on the top and are secured by flat clamps as long as the width of the tie, the back of each clamp entering slots in the ribs of the tie. Each rail is held by a U bolt passing through the clamps and twisted so as to pass through the middle web of tie, one leg of the bolt being in each channel.

No. 509387; date, November 28, 1893; Bernard C. J. McGuire, Summer Hill, Pa.: A cast-iron tie of ⊥ section, enlarged to rectangular section at end rail seat. The bottom is corrugated. The outer flange of rail is held by a fixed lug and the inner flange by a vertical spike, which is prevented from working loose by a key driven horizontally through the tie and spike.

No. 511072; date, December 19, 1893; Hippolyte A. de Raismes, Elizabeth, N. J.: The tie is made of a tee iron laid on its side ⊢ and having each end bent in place into a kite-shaped loop. Resting on each loop is a steel chair having a fixed inner lug and projecting pieces to bend down on the outer flange of the rail.

No. 511226 and No. 511227; date, December 19, 1893; Leander E. Whipple, New York, N. Y.: A tie of ✕ section formed by two curved plates back to back, with a top plate and a bottom plate (or bottom straps) having the ends bent to receive the ends of the curved plates. To the top of the tie are riveted two tie plates with lugs for the rails (No. 327843).

No. 511316 and No. 511317; date, December 19, 1893; Thomas M. Brintnall, of Medina, and H. C. Bradley, of Warren, Ohio: A tie of inverted channel section, with thickening rib on the underside of the top table, and gib and cotter rail fastenings. The ties may be stiffened by interior Λ-shaped truss plates.

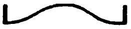
No. 512877; date, January 16, 1894; Neils Gunderson, Ogdensburg, N. J.: Flat stringers with ribs on the edges forming a channel for the rail base. The rail is compound, having a ⊥ base with a flangeless T part bolted to it.

No. 513445; date, January 23, 1894; Herbert L. Stillman, Charlestown, R. I.: A flangeless T rail with the web bolted between two wooden longitudinals of triangular section, with cross-ties at intervals.

No. 513712; date, January 30, 1894; Arthur J. Moxham, Johnstown, Pa.: Very similar to No. 508049 and No. 505988, but with the tie widened by rectangular or triangular projections at the rail seats.

No. 513792; date, January 30, 1894; John C. Lee, Beaver, Tex.: A solid tie with raised rail seats, and the rail held by two ┌ clamps secured by a horizontal bolt through clamps and rail seat.

No. 513838; date, January 30, 1894; Edward H. Stone, Simla, India: A cross-tie of the Rendel pattern (see India), with pressed lugs, but having a distance piece between one lug and rail flange and a key between the other lug and rail flange, so that the lugs are far enough apart to admit the rail base direct, and adjustment of gauge may be effected by the use of different sizes of distance pieces.

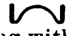
No. 514179; date, February 6, 1894; George W. Cady, Providence, R. I.: Longitudinals composed of wavy plates  with rails secured by clamps to the top of the ridge, and the vertical flanged ends bolted to the web of a piece of old rail forming a cross-tie.

No. 514243; date, February 6, 1894; George H. Sellers, Ridley Park, Pa.; A rectangular frame tie of angle iron with corrugated flange. A bearing piece is placed within the frame near each end, forming the rail seat, with pockets of wooden cushions, and the fastenings consist of four horizontal hook bolts to each rail.

No. 515409; date, February 27, 1894; S. A. Roake and F. G. Smith, Williamsbridge, N. Y.: An inverted channel tie of cast iron, having cross ribs or diaphragms. The top table is higher outside the rail seats, the rise fitting the outside of rail. A horizontal pivoted bar between the rails has its ends formed to bear upon the inner flanges of the rails.

No. 515431; date, Februry 27, 1894; Moses G. Hubbard, Chicago, Ill.: A tie of semicylindrical section, with top table flat, or slightly convex or concave. Each rail is held by a U bolt and two clamps. (No. 464984.)

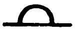
No. 515551; date, February 27, 1894; Adolph C. Petzman, Philadelphia, Pa.: A rectangular frame tie, in place, with wide ends forming rail seats, with lugs the full width of the inner half of each rail. Seat is loose and secured by a horizontal bolt through it and the fixed part of the end.

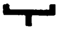
No. 516001; date, March 6, 1894; Joseph Dyson, Cleveland, Ohio: A cross-tie of inverted semicircular trough section, with vertical exterior flanges, forming two narrow open channels . The rails are secured by studs or bolts to channel-shaped rail seats, resting within the vertical sides of the tie.

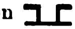
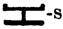
No. 517236; date, March 27, 1894; Minard A. Possons, Cleveland, Ohio: A cross-tie of inverted channel section. Each rail is held by a flat clamp in the tie, having lugs which grip the rail.

No. 517302; date, March 27, 1894; Albert S. Roberts, Norwalk, Ohio: An open channel tie, with a hollow box chair or rail seat inside the channel at each end. Each rail rests on a base plate, with lugs underneath, fitting inside the box and secured by a through bolt, while the rail is held by lugs on top of the plate.

No. 517369; date, March 27, 1894; John Temple and James C. Ward, Wilsonburg, W. Va.: A bar tie of rectangular section bent down at each rail seat to form a pocket for wooden rails for mines, the ends of the tie being bent up vertically and reaching to the top of the rail or stringer. Wedges are driven between the stringer and the vertical end of the tie.

No. 517447; date, April 3, 1894; Robert Dinsmore, Weston, W. Va.: A semicylindrical tie with flat base , the top cut away at each rail seat to allow the rail to rest upon an interior block carrying the inner lug. A horizontal key through the tie secures the block.

No. 517585; date, April 3, 1894; James Neafie, Boonton, N. J.: A cross tie of  section formed of two Z-bars bolted through the lower webs. The rail clamps extend the full width of tie and are held by a U bolt, or there may be four hook bolts to each clamp, and depending web of the clamp fits between the lower webs of the tie.

No. 517915; date, April 10, 1894; Albert G. Budington, Austin, Tex.: The tie is an open channel of this section , with a -shaped block under each rail. The rails are secured by studs driven through tie flanges and by clamps bolted to these flanges. Switch rails can be laid by merely inserting an extra block and drilling stud holes. (No. 464424.)

No. 518439; date, April 17, 1894; W. T. Armstrong and George H. Wadsworth: The tie is a plain inverted channel, and the clamps are flat plates with a rib fitting a slot in the tie, and each clamp is secured by a vertical bolt.

No. 521158; date, June 12, 1894; Frank P. Feuerbacher, Oklahoma, Okla.: A flat plate tie with ends bent vertically down then returned upon themselves and back over the top table to form outer clamps for the rail flanges. The inner flanges are held by bolted clamp plates.

No. 522974; date, July 17, 1894; Robert E. Daniels, Youngstown, Ohio: A tie anchor consisting of a curved piece of corrugated plate with the top fastened to the bottom of the tie, the plate being at right angles to the rail. (No. 482979.) (*See* Daniels tie.)

No. 524359; date, August 14, 1894; Enoch L. Taylor, Philadelphia, Pa.: A cross-tie of inverted channel section with the ends passing through the sides of two rail bearers of trough or angular form or , the bearers being adjustable so as to fit the position of rails at switches, etc. (*See* No. 461775.)

No. 524909; date, August 28, 1894; Newton Benjamin, Elmira, N. Y.: Cross-ties of fork shape in plan laid with the single and double ends alternating. Each tie made of two ⊥ bars bolted together at the stem, with rail chairs and lugs between them. A short piece of ⊥ iron is bolted against each arm of the fork with chairs and lugs between. Three pieces may be used and the rail seats may be pieces of inverted track rails with the flanges of the ⊥ bars resting on the head.

No. 525927; Enoch L. Taylor, Philadelphia, Pa.: A tie consisting of two supports of inverted trough section parallel with the rails, and connected by a transverse ⊥ bar passing through slots in the sides of the supports. Lugs on the supports hold the inner flanges of the rails, and notches on the tiebar hold the outer flanges. (*See* No. 461775; *see also* Columbian tie, United States, in part 1, and also Taylor tie, in the original report.)

No. 526603 and No. 526604; John Albrecht, Massillon, Ohio: Hollow box ties. The fastening of the first consists of a vertical block in the tie, having at each side lug fitting a recess in the lower part of the rail clamp, the block being thus suspended by the clamps, which are pivoted on pins through the tie. The rail rests on top of this block, and the intention is that the depression of the rail and block under wheel loads will spread apart the lower ends of the clamps and cause the upper ends to bear tightly upon the web and flange of the rail. In the second patent the tie has lugs for the inner flanges of the rails, and the outer flange of each is held by the notched upper end of a curved clamp of this form whose lower end rests inside the tie.

No. 528309; William R. Smith, Riverside, Ohio: A channel-shaped tie with each rail resting on a plate supported by coil springs in the tie.

No. 529997; John Albrecht, Massillon, Ohio: A box tie with slots for long S-shaped lugs with the top resting on rail flange and bottom on underside of tie; the lower ends of the lugs are forced apart by cams inside the tie.

No. 532364; Ellery C. Davis, Crookston, Minn.: A channel tie with inverted channel support fitted inside for each rail seat. Rail fastened by spikes having grooves into which fits a wedge locking plate driven through the inverted channel.

Addenda.—No. 349913; date, September 28, 1886; and No. 356016; date, January 11, 1887: J. H. Tozer, London, England. (See Tozer tie in former report.)

No. 527688; date, October 16, 1894; Jesse W. Cowdrick, Ogdensburg, N. J.: A hollow steel tie of oval section, with slot cut along middle of top surface and two cross cuts at each rail seat, forming partly detached pieces upon which the rails rest, but which have the ends bent inward so as to allow of a plate being inserted between them and the rail. A flat clamp plate holds each rail flange, and a brace supports the outer side of the bottom of rail head. Two bolts on each side of the rail (8 bolts per tie) pass through the plate, clamps, and brace. The tie is to weigh 240 pounds, and is estimated to cost $2.40 in quantities.

No. 528309; William R. Smith, Riverside, Ohio: A tie of channel section ⊔ with each rail resting on a plate supported by three vertical coiled springs placed in a row across the tie. The rail fastenings are pivoted lugs.

Addenda (omitted from list in former report).—No. 349913; date, September 28, 1886, and No. 356016; date, January 11, 1887; James H. Tozer: Steel ties of the Tozer type, described in former report, page 72 and plate No. 4.

Bridle rods, or straps to hold rails together, used in conjunction with wooden ties: Nos. 441416, 442506, 442643, 445449, 457596, 477943, 490868, 518348.

Fastenings for rails on wooden ties: No. 443274; December 23, 1890; William Goldie, West Bay City, Mich.: A pair of └─┐-shaped clamps, the backs driven into the tie and each held by a vertical screw spike or lag screw.

No. 444988 and No. 446282; February 10, 1891; Thomas J. Bush, Lexington, Ky.: Interlocking bolts forming an X under the rail, with nuts and clamps on the rail flanges.

No. 450305; April 14, 1891; C. C. Wrenshall, Anniston, Ala.: A headless screw spike screwed into the tie, with a clamp fitted over its upper end and secured by a nut.

No. 458230; August 25, 1891; M. Geng, Cologne, Prussia: A base plate, or chair, with two vertical ribs along each side, and notched keys driven through slots in the ribs, so that the ends of the keys rest on the rail flange.

No. 488195; December 20, 1892; William Goldie, West Bay City, Mich.: A twisted spike (or screw with long pitch) screwed into the tie, and having a threaded upper end for a nut to hold the clamp plate.

No. 490704; January 31, 1893; James M. Woodcock, Bridgeport, Ohio: Screw spike with flat head bearing on the rail flange, and having a projection on top to support the bottom of a brace plate whose upper end fits under the rail head.

No. 496254; April 25, 1893; John T. Feindel, Somerville, N. J.: An inclined plate with one end hooked over rail flange, and the other bent at right angles and driven into the side of the tie.

No. 502361; August 1, 1893; C. C. Holt, Lawrence, Mass.: A clamp of ┐ shape with a vertical lag screw.

No. 505743; September 26, 1893; Alfred T. Abbott, New York, N. Y.: A spike or ∩ staple with fluted surfaces.

SUMMARY.

Concrete block ties: No. 479808 and No. 484855.

Fastenings for metal ties: Nos. 453886, 472034, 483518, 491206, 513838.

Joint for rails on metal ties: No. 493802.

Ties utilizing old rails: Nos. 430553, 445325, 470585, 472901, 482967, 514179, 524999.

Ties for street-railway tracks: Nos. 427109, 430780, 446446, 448005, 449117, 452333, 454179, 477679, 495146, 505988, 508049, 513712.

Combination ties of metal and wood: Nos. 423929, 425937, 426051, 435004, 435164, 439174, 441416, 443594, 451804, 470700, 485097, 486741, 501678, 508575, 512877, 513445.

Longitudinals: Nos. 426051, 427109, 429436, 429613, 430197, 430590, 431172, 433803, 435768, 451781, 452333, 457735, 467432, 470641, 470904.

Portable track: No. 426877.

APPENDIX 3.

CAST-IRON VERSUS STEEL SLEEPERS.

[Note by the Consulting Engineer to the Government of India for State railways, March 16, 1894.]

1. Reports from various sources seem to show that the steel sleeper is rapidly oxidized and destroyed in saline soil, more particularly in sodium salts, and my observations during my tours of inspection fully support this view. But doubts have been also expressed as to the durability of the sleeper under better conditions, and from what I have seen lately I am inclined to think that these doubts are sufficiently well grounded to justify another inquiry such as made by the Director-General of Railways in 1889, but covering all the lines on which this sleeper is now in use. These sleepers are to be found, I think, on the following lines: Northwestern Railway, Bengal-Nagpur Railway, Southern Mahratta Railway, Nizam's Guaranteed Railway, South Indian Railway, Eastern Bengal Railway, and East Coast Railway, but on the last-named they have been down so short a time that inquiry as to durability from that line will not be necessary. I think that close inspection will, in the case of sleepers that have been down say six to eight years, reveal considerable if not serious corrosion underneath, and round the edges of the lugs and at the rail seat.

2. If it were not for this fatal weakness the steel-stamped sleeper might be held to have fulfilled its promise of being the best substitute for the transverse wooden sleeper, while its faults, which would certainly not condemn it, are its "harshness" under traffic and the waste of metal in its tieing function, as compared with the cast-iron plate or bowl. Another fault which may not be so obvious, is its lightness. The recent heavy type weighs only 135 pounds, whereas, as I showed in a previous note, the—

	Pounds.
Indian Midland pot sleeper weighs	236
East Indian Railway plate sleeper weighs	230
Sâl sleeper weighs	220
Sâl sleeper with chairs and spikes, say	280

It is now clearly recognized that a good road for heavy fast traffic must be a heavy road, both in rails and sleepers, and it is no uncommon thing to quote the fitness or unfitness of a road for such traffic by the weight per mile of its permanent way. I should consequently be quite prepared to assert that a sleeper weighing only 135 pounds, specially with rails of only 75 pounds per yard, is too light for our standard gauge for fast traffic, the effect of which will be found in the cost of maintenance, or in rough running. I think that for high-speed traffic on our standard guage the sleepers would not be a bit too heavy if they weighed 250 pounds each. A sleeper of this weight in steel would clearly be of prohibitive cost, if it had no other faults, and we have to bear steadily in mind that the steel sleeper when rejected is practically valueless at present.

3. Thus it is time to consider, in anticipation of the result of the inquiry I have recommended above, what other type of sleeper we should adopt. My own impression, after discussion with many of our engineers, is that the average life of a steel sleeper will not much exceed twelve years, which is about the life of a good hard-wood

sleeper, but the wooden sleeper can not now be got in quantity, without long previous arrangements, if even then, and the price is rapidly approaching that of the steel sleeper. As used now, our supply is limited to the following timbers: Teak, sâl, pingadu, asun, deodar, and, when I say, "as used now," I refer to the possibility of getting a satisfactory design for a sleeper in which metal and wood will be combined, and in which any reasonably good hard wood could be used and less of it. This, however, is by the way. We must now recognize that the supply of wooden sleepers is distinctly below the demand, and if any new line of, say, 200 miles in length were to be started at once, the sleepers could not under the most favorable conditions be forthcoming within eighteen months or two years. Creosoted pine from home is always a possible resource, but though cheap in first cost they are dear in the long run.

4. I think, therefore, that if we want a good, a heavy, and a durable road we shall find true economy in the cast-iron sleeper. In this I find I am supported by my distinguished predecessor Sir Guilford Molesworth. Writing in September, 1893, I find he says:

"For a metal sleeper I am inclined to prefer cast iron to wrought iron or steel. It is true that a lighter sleeper may be obtained in wrought iron or steel, but as the corrosion is much more rapid in those metals, the same durability can not be insured in the thinner and more easily corrodible sleepers as is possible in the thicker sleeper of cast iron. Moreover, cast-iron sleepers, when useless, may be remelted, but a thin wrought iron or steel sleeper, when thoroughly corroded, is valueless. I believe, too, that it has been found that if sleepers are too light the maintenance becomes heavier in consequence of the small inertia of the sleepers."

In another note in May, 1885, he says:

"I quite agree with the consulting engineer (Calcutta Circle) in the preference he accords to cast iron when compared with steel as a material for sleepers. I do not agree with him that steel may perhaps be equally durable with cast iron. Taking into consideration the greater rapidity of corrosion and the smaller thickness of metal in the steel, I conclude that its durability in sleepers will probably be only one-sixth that of cast iron."

5. The cast-iron sleeper is, of course, largely in use already on Indian railways. The bowl or the plate types are in use either partly or exclusively on the Great Indian Peninsula Railway, the Bombay, Baroda, and Central India Railway, the South Indian, the Madras, the Oudh and Rohilkhand railways, the Indian Midland, the Eastern Bengal, the Northwestern, and East Indian railways. On the latter the plate sleeper Denham-Olpherts is the standard, and other sleepers (wood) are only used where they are distinctly more economical. On the other hand, the steel sleeper, which was introduced on the frontier lines in 1885, has been mostly used on State lines. It is to be found also on the Southern Mahratta, the Bengal-Nagpur, and the Nizam's Guaranteed railways. In its latest development it is under supply to the East Coast Railway, but there we are faced with the difficulty of finding a large supply of sleepers for tracks where saline soil is found and where we can not safely use the steel sleeper.

6. As to the durability of the cast-iron sleeper, we have ample and favorable experience. On the Madras and Great Indian Peninsula railways there are miles of cast-iron sleepers which have certainly been under traffic for twenty-five years and are still quite serviceable, and there can be no doubt that properly designed bowls or plates in good ballast would last fully this time. The great advantage of this sleeper is that on rejection its value as scrap is from 60 to 80 per cent of its original value, the figure varying according to the distance from the center of the demand or point where recasting can be done. Another prime advantage is that, whether in remaking or in original manufacture, the cast-iron sleeper can be made in the country, and one item—not a small one—eliminated from our home remittances. The breakage of cast-iron sleepers in the road is very small, but depends on the

design, the ballast, and the system of packing; but on the average the figure for breakage would, I think, be about 0.4 per cent per annum.

7. On the other hand, the first cost of a cast-iron sleeper, and certainly one of such a weight as I have indicated above, would compare unfavorably with the cost of a cast-steel sleeper weighing 135 pounds, and still more as compared with timber. The relative cost of sleeepers can not be given with any degree of accuracy for the general question of a sleeper supply in India. The figures would be complicated by variables relating to supply and demand at the time, to distances of centers of supply and demand, the condition of freight and existence or nonexistence of effective competition on the part of suppliers, but a rough comparison of the cost of sleepers as now used might be somewhat as follows: Taking a hard wood sleeper at 100, the stamped steel would be about 130, and the cast-iron sleeper 155. Thus the last named, even at this present weight, will cost considerably more at the outset than the steel, but, on the other hand, it may be certainly expected to last twice as long, and when rejected to be worth from 60 to 80 per cent of its first cost; while, under present conditions, the rejected steel sleeper will be practically valueless. Again, if we attach proper importance to the need of a heavy sleeper, and to its economy in maintenance, the comparatively light steel sleeper must be regarded unfavorably, while, if we were to increase its weight to anything like that of a cast-iron sleeper, the cost would be far more than the cast iron and it would still show the great disadvantage of having a merely nominal value on rejection.

8. If we adopt cast iron in lieu of steel for our metal sleepers, a few words may be given to the question of design. A very large mileage of cast-iron sleepers consists of bowls, either round or elliptical in plan, and with double or single rail seats. The East India Railway alone has adopted the plate or flat bottom as their standard, and in this, I think, they are right. In a report submitted as long ago as 1885 to the Railway Conference at Brussels, it was stated that European opinion might be summarized as in favor of a sleeper with a flat undersurface. In fact, as to bearing or, indeed, in any other way, the bowl has no advantage that I can see, and has the disadvantage in bad ballast of having no lateral grip, whereas the plate sleeper carries strong cross fillets for this purpose. I do not like the double seating on the oval pots as on the Great Indian Peninsula and Indian Midland railways. It is a mistake. Theoretically, the proper bearing for the rail on a transverse sleeper would be a knife-edge.

9. A point in connection with adoption of a cast-iron sleeper, if it is to be obtained in India, is that the manufacture can only be carried out on a comparatively small scale at present; but if it was generally known that the Government of India has adopted this as a standard for state lines, a great impetus would be given to the industry, and we might hope, before long, to be largely independent of supplies from England.[1] It might also be expected that to some extent stocks of sleepers would be kept on hand in view of a sudden demand.

10. It will be gathered from the foregoing remarks that I think we should be more careful in ordering out further supplies of steel sleepers until we have better knowledge as to their durability, and that we can not do wrong in substituting for these, for the present, a cast-iron sleeper. The only difficulty about this is the increased first cost as compared with the steel sleeper of the present weight, and in the cost for land carriage, which would be fully 50 per cent more in the case of the cast-iron sleeper. These two items, first cost and cost of carriage, are, I freely concede, very important factors in the decision, and in the case of new lines, on which the prospects are uncertain, and, where cheapness in first cost is essential, the steel or even the cheapest wooden sleeper would be preferred. But for renewals on our older lines we might safely require the adoption of the cast-iron sleeper.

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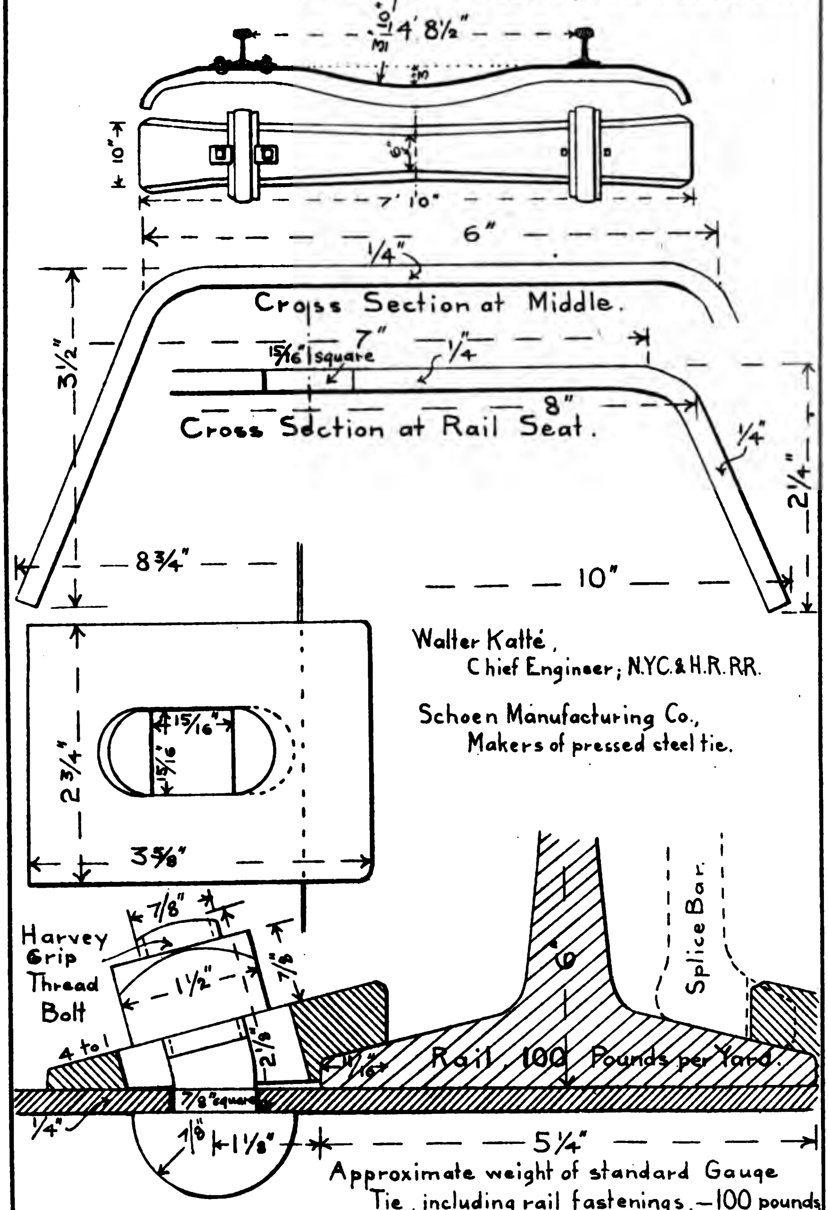
[1] The weight of cast iron per mile for such sleepers would be, for broad gauge, about 200 tons.

UNITED STATES PLATE Nº 1.

NEW YORK CENTRAL & HUDSON RIVER RAILWAY.



Walter Katté,
Chief Engineer; N.Y.C.& H.R.RR.

Schoen Manufacturing Co.,
Makers of pressed steel tie.

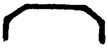
Approximate weight of standard Gauge Tie, including rail fastenings, —100 pounds.

Tie formed from 0.10% carbon Bessemer steel plate, — 8' 4" x 13⅝" x ¼".

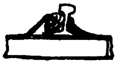
Pattern adopted, July, 1892. 18,000 made in 1893.

E.E.Russell Tratman, C.E., Tribune Building, New York. 1893.

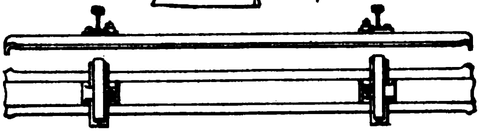
PLATE No. 2.

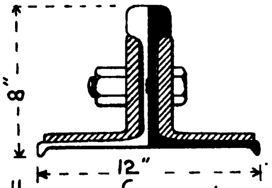


Heindl Tie (Austria).

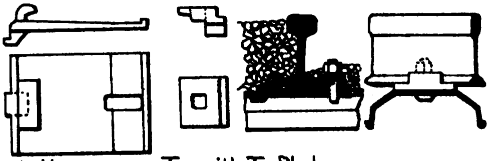


Riley Tie (England).

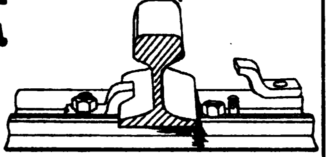


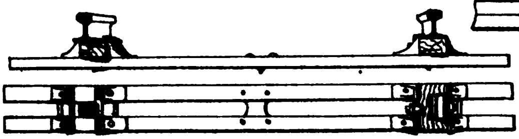


Haarmann Compound "Self-Bearing Rail.

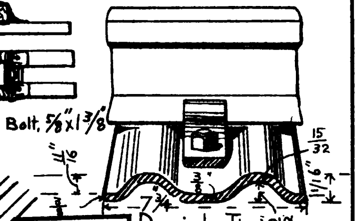


Haarmann Tie with Tie-Plate.

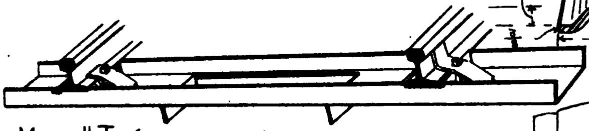




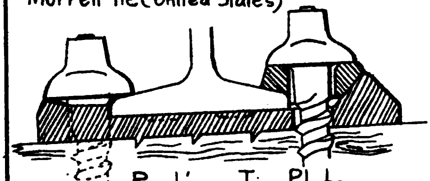
Price Tie (United States).



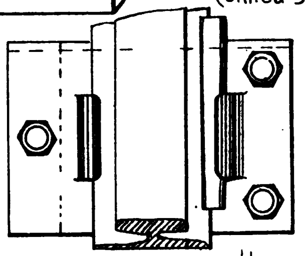
Daniels Tie
(United States)

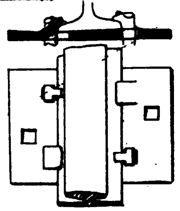


Morrell Tie (United States)

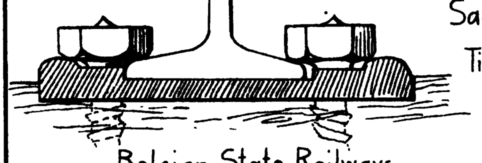


Post's Tie-Plate.

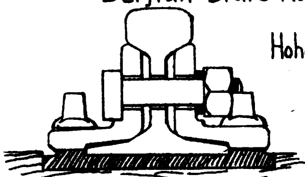




Sandberg's Tie-Plates.

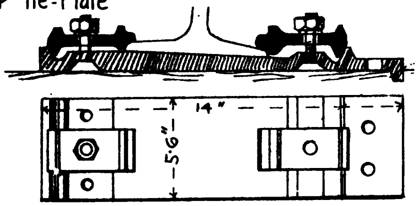


Belgian State Railways.



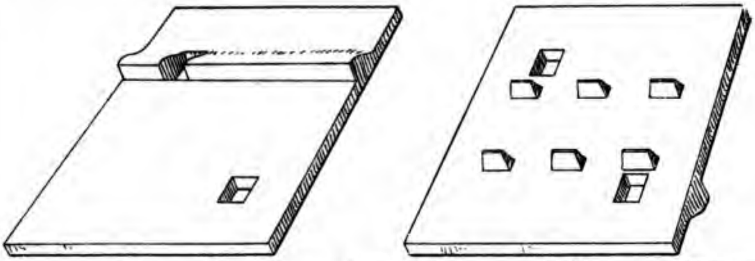
Paris, Lyons & Mediterranean Railway.

Hohenegger Tie-Plate

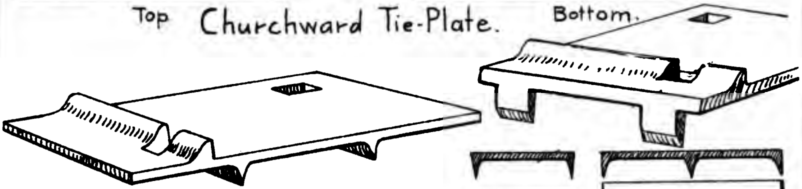


E.E. Russell Tratman. C.E.

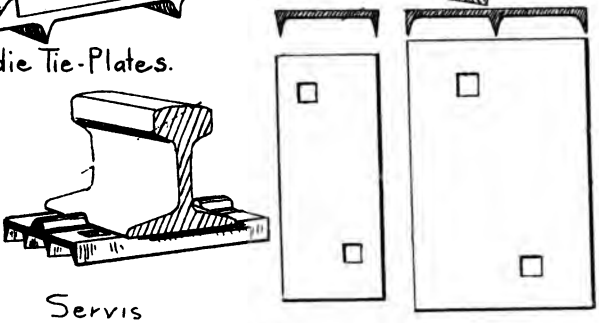
PLATE Nº 3.



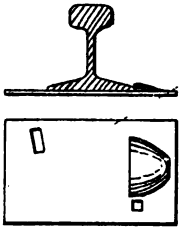
Churchward Tie-Plate.



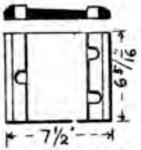
Goldie Tie-Plates.



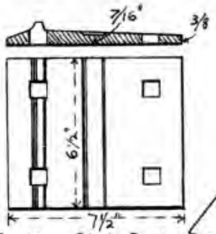
Servis Tie-Plates.



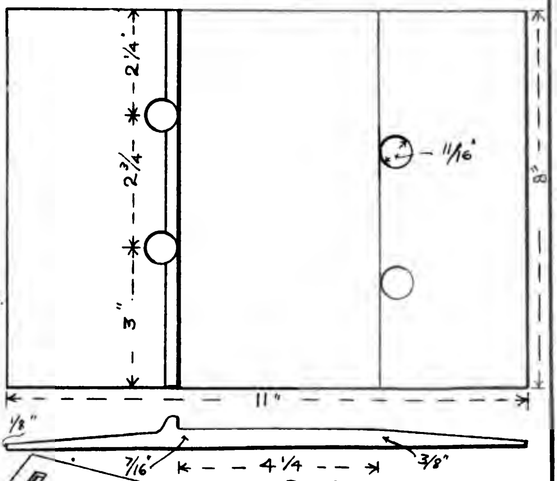
Shoulder Tie-Plate.



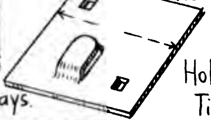
Prussian State Railways.



Indian State Railways.



Southern Pacific Railway.

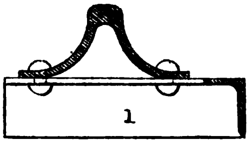


Holgate Tie-Plate.

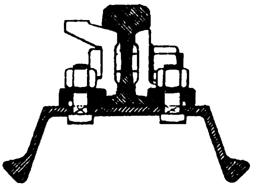
E. E. Russell Tratman. C.
New York.

(HISTORICAL.)

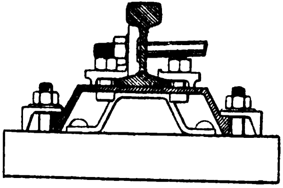
PLATE No. 4.



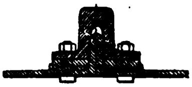
—Barlow.



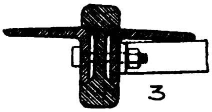
10 -Rhenish.



11 —Hogenegger.

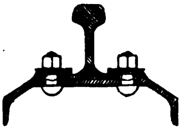


2 —Macdonnel.

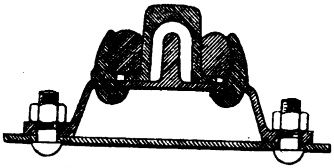


3

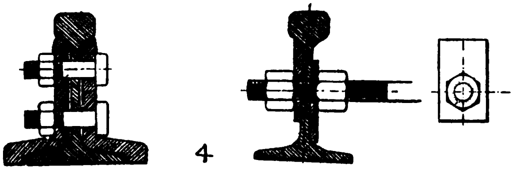
—Bridges Adams.



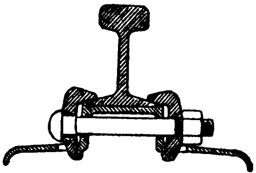
12. -Hohenegger.



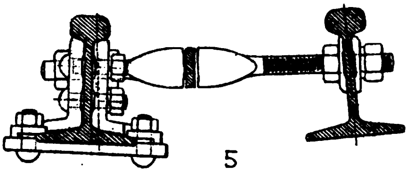
13. -Heusinger von Waldegg.



—Hartwich: (Alsace-Lorraine.)



14 —Haarmann.



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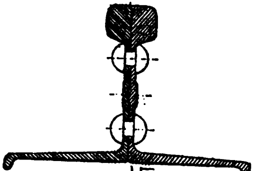
—Hartwich: (Bavaria.)



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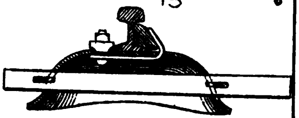
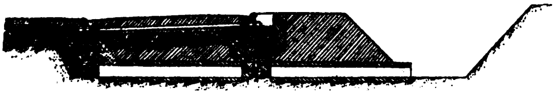
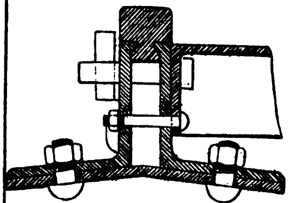
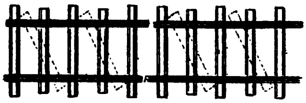




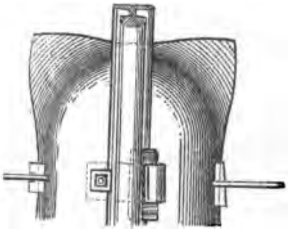
6. —Hartwich: (Alsace-Lorraine.)



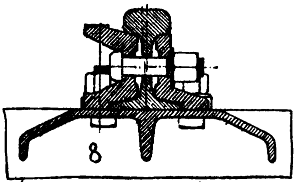
7. —Daelen.

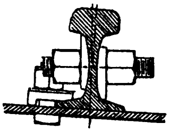


18. —Laying Legrand Ties.



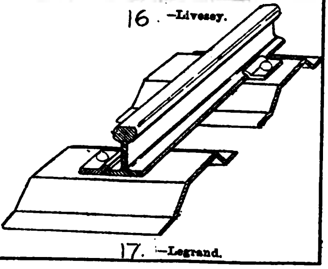
16. —Livesey.





9

(E. E. Russell Tratman)—Hilf. (Alsace-Lorraine.)



17. —Legrand.

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